Prototyping the WASA DIRC

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Supported by BMBF and FZ Jülich

Friedrich-Alexander-Universität
Erlangen-Nürnberg

WASA-at-COSY

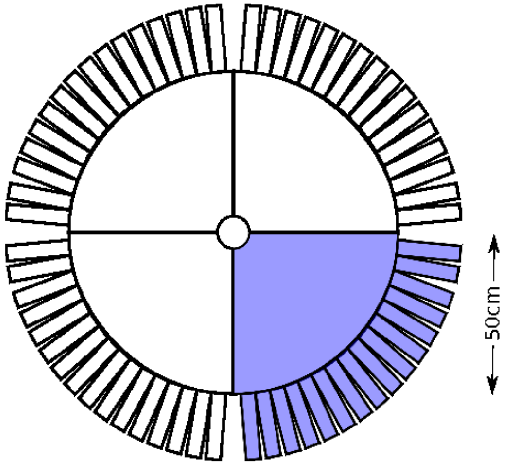
CONTENT

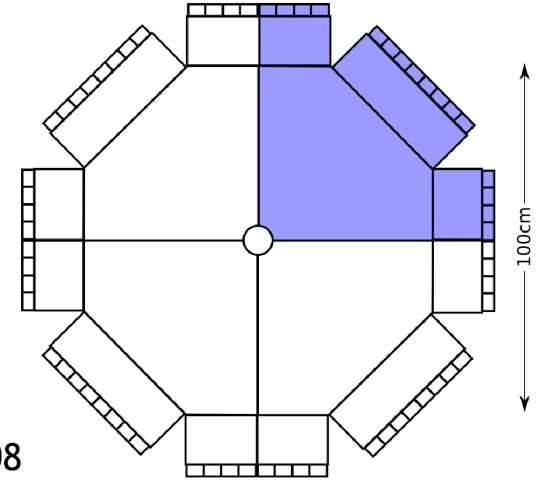
- Prototyping a DIRC for WASA
- Erlangen Prototype
  - CAD Design
  - Performance Simulations
  - Manufacturing
- Photomultipliers
  - Gain & Uniformity
  - QE Studies
  - Readout
- Radiators and Optics
  - Surface Studies
  - Focusing Properties
- Timeline, Summary and Outlook

Prototyping a DIRC for WASA

- First tests show feasibility*

  → enhanced prototype shows performance
  - challenge: low number of detected photons
- Two concepts will be tested
  - circular shape with mirrored optics
    - manufactured in Tübingen
  - octagonal shape with internally reflecting optics
    - manufactured in Erlangen
  - use same PMTs for readout
  - beam tests behind TOF@FZ Jülich

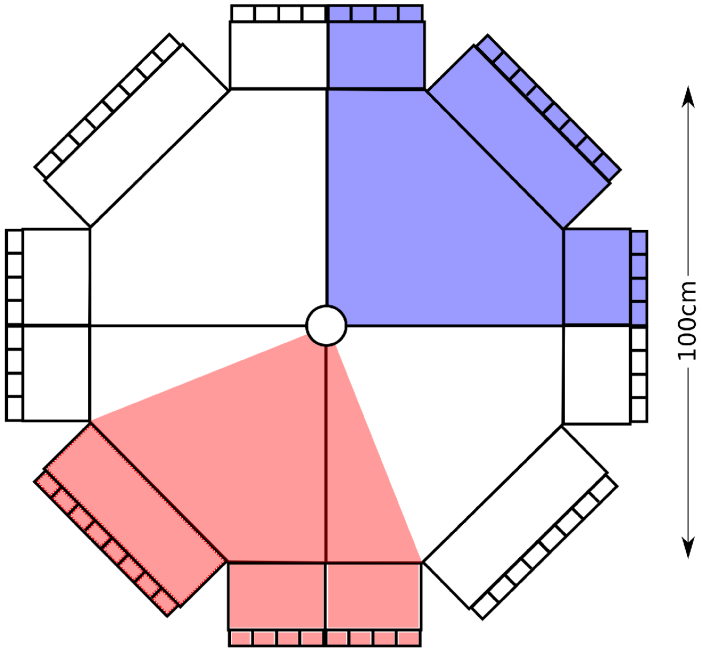


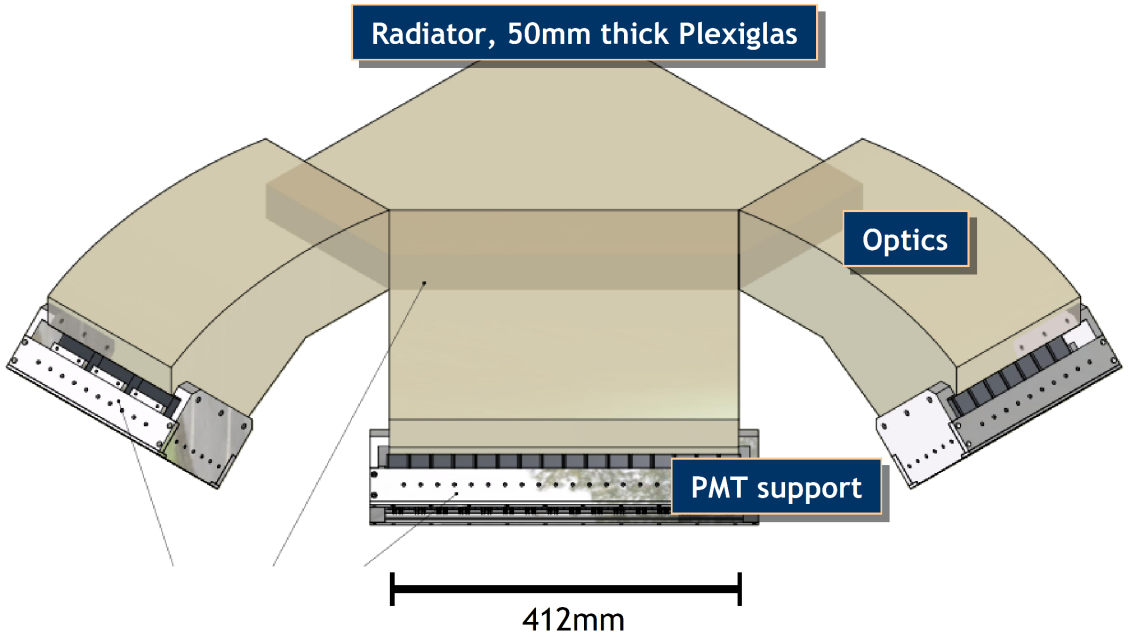


*W. Eyrich et al, A DIRC Detector for WASA-at-COSY, 2010, JINST 5PO1008

ERLANGEN PROTOTYPE – CAD Design

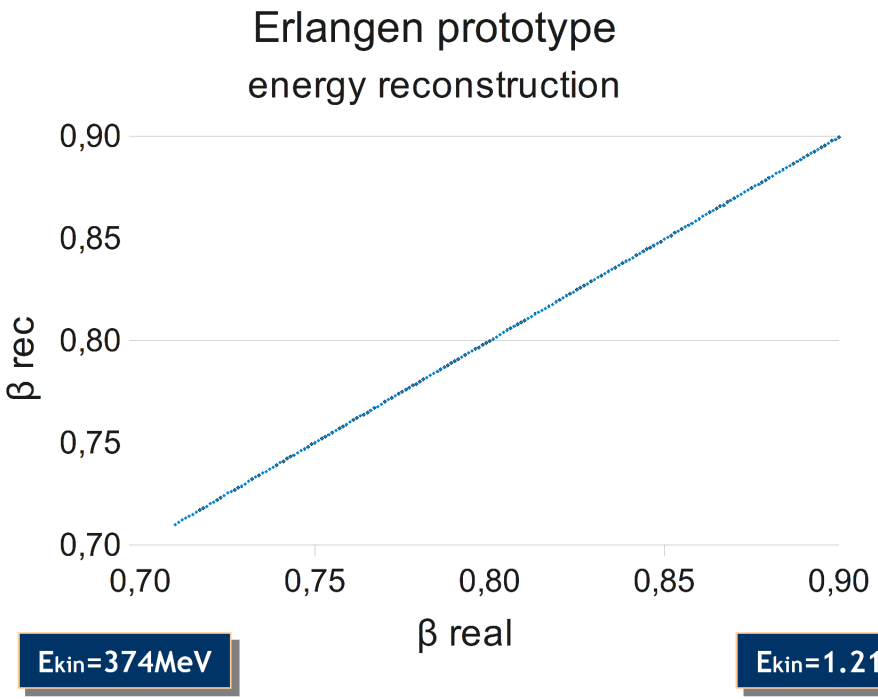
- One quarter of an octal detector, optics optimized by Klaus Föhl



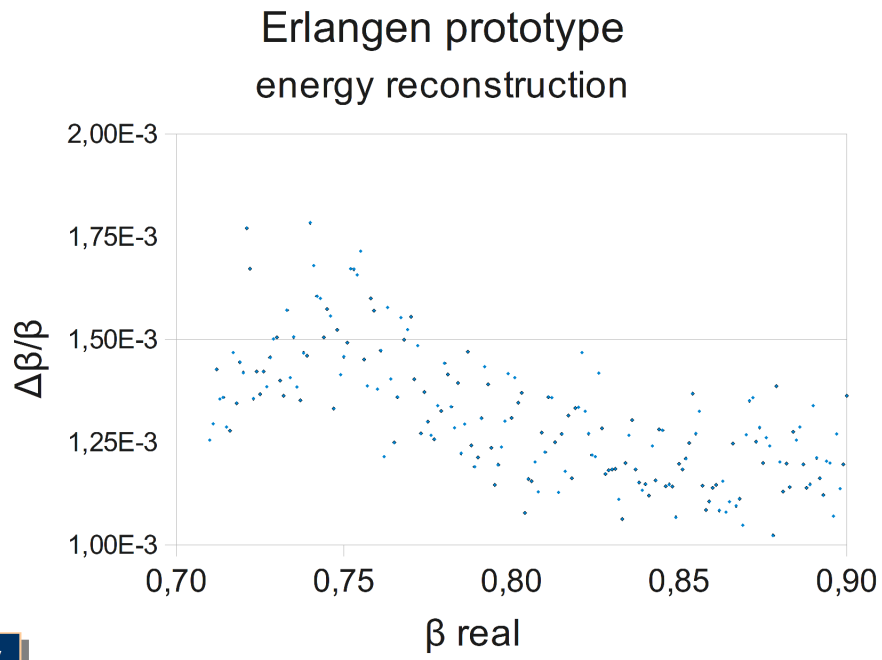


ERLANGEN PROTOTYPE – Performance Simulations

- Simulations concerning the energy resolution for protons done by Klaus Föhl



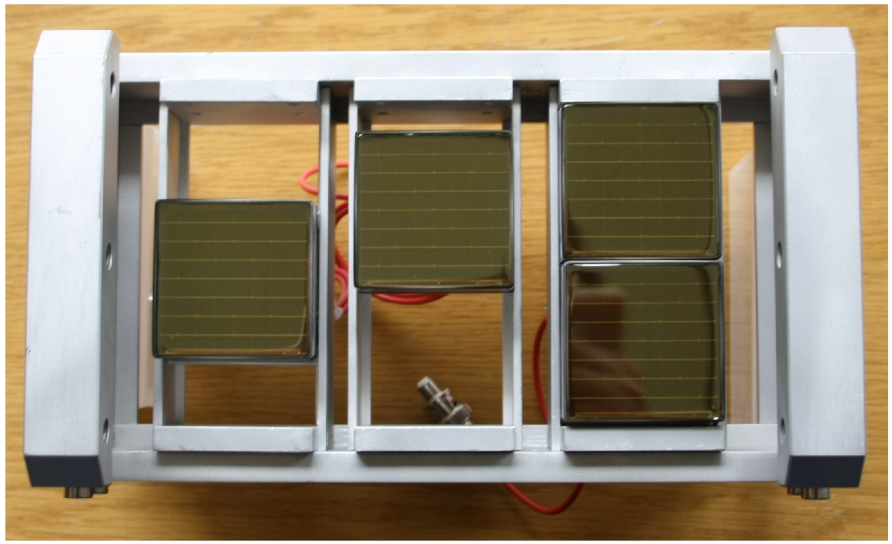
Ekin=374MeV

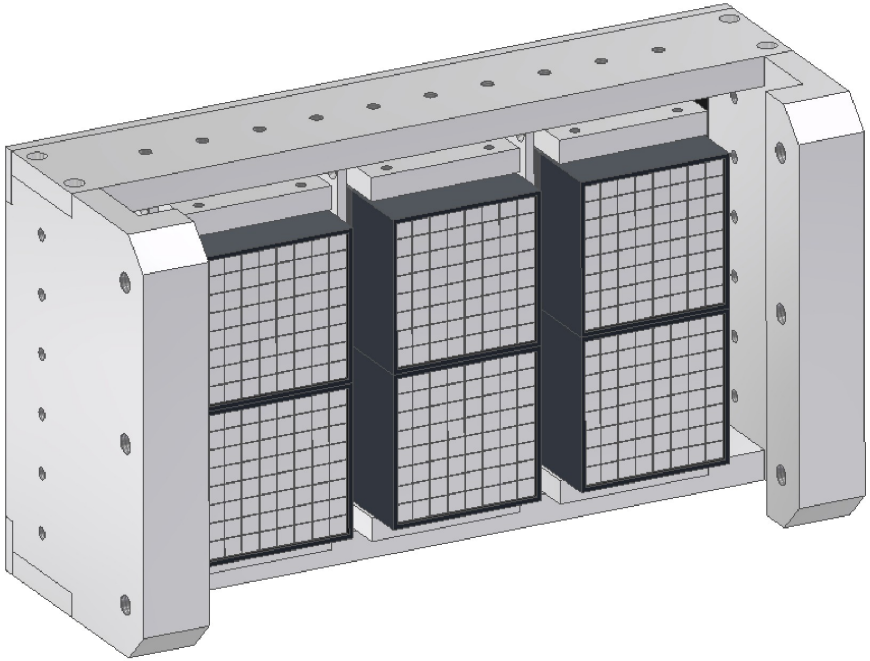


Ekin=1.21GeV

ERLANGEN PROTOTYPE - Manufacturing

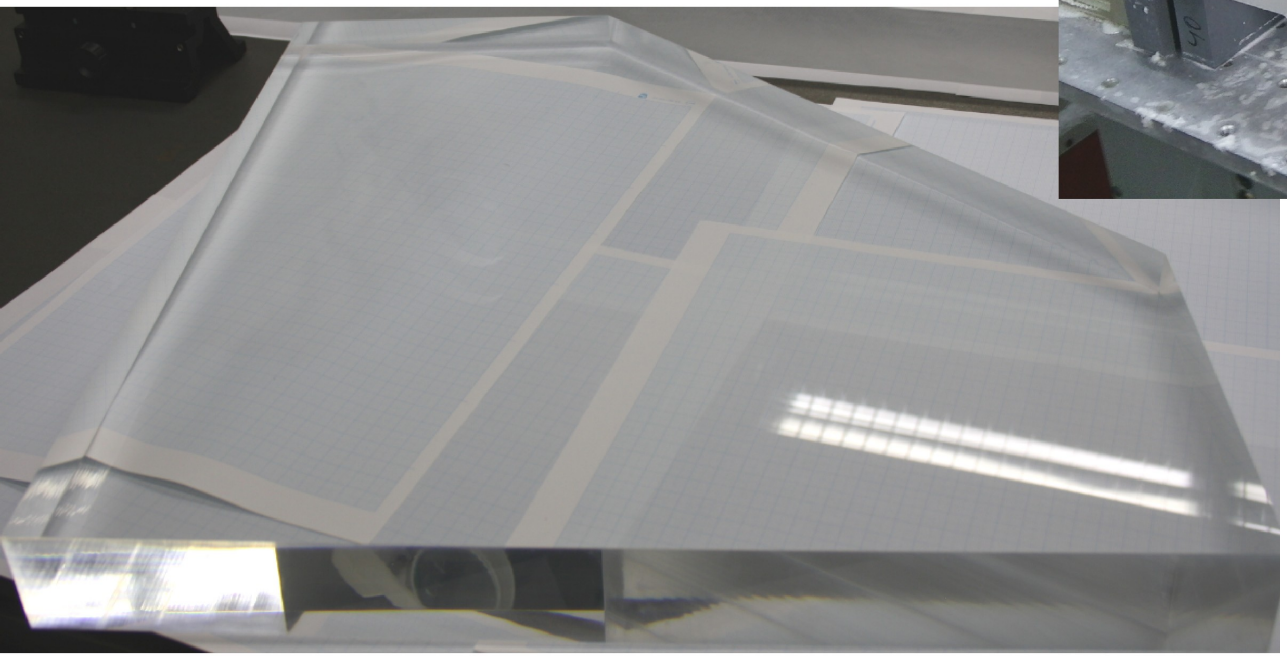
- Detailed view of the PMT support structure
  - up to 8 PMTs for small FE (full focal plane)
  - PMTs movable





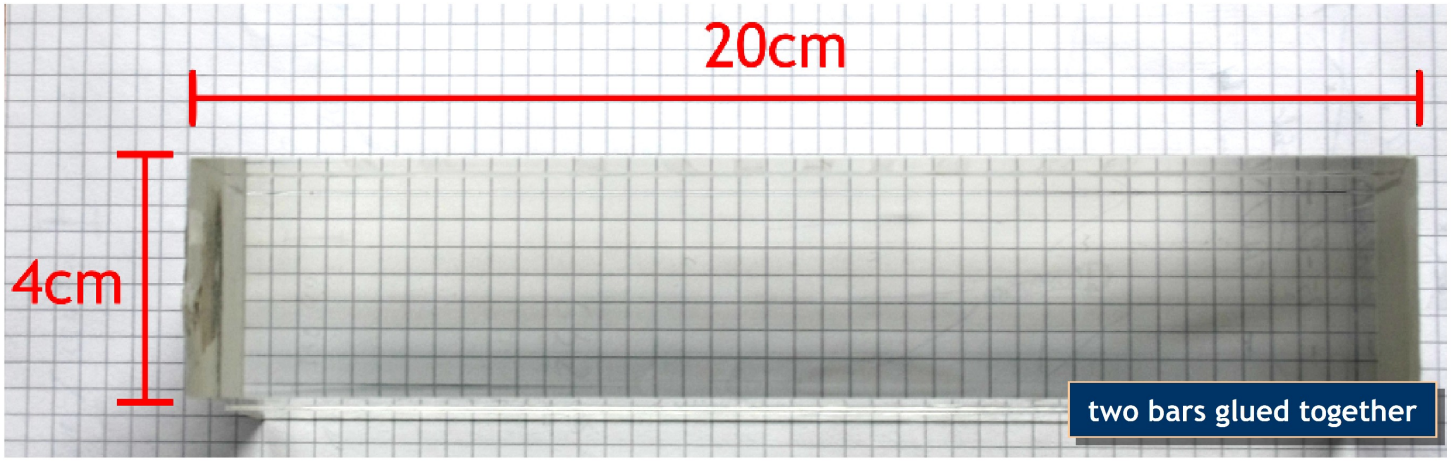
ERLANGEN PROTOTYPE – Manufacturing

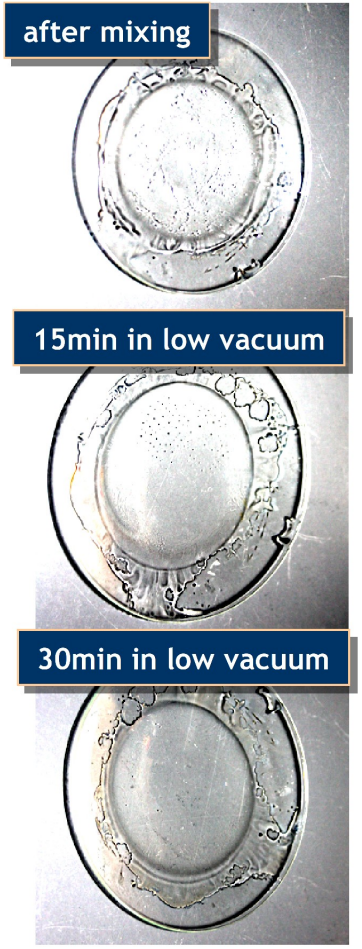
- Radiator: casted plate, cut to size
- Optics: machined from block
  and polished



ERLANGEN PROTOTYPE - Manufacturing

- Plexiglas glueing
  - use optical cement Saint Gobain BC600
    - >98% transmission
    - Bond strength >125kg/cm^2
  - insert into vacuum to reduce air bubbles
- Silicone pads/optical grease for PMTs





PHOTOMULTIPLIERS - General conspectus

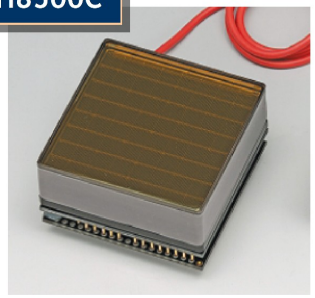
- Number of detected Photons low (max 13)
- Hamamatsu R8900 16-channel PMA
  - active area 23.5x23.5mm² (81%)
  - voltage divider build in Erlangen
  - available with super and normal cathode

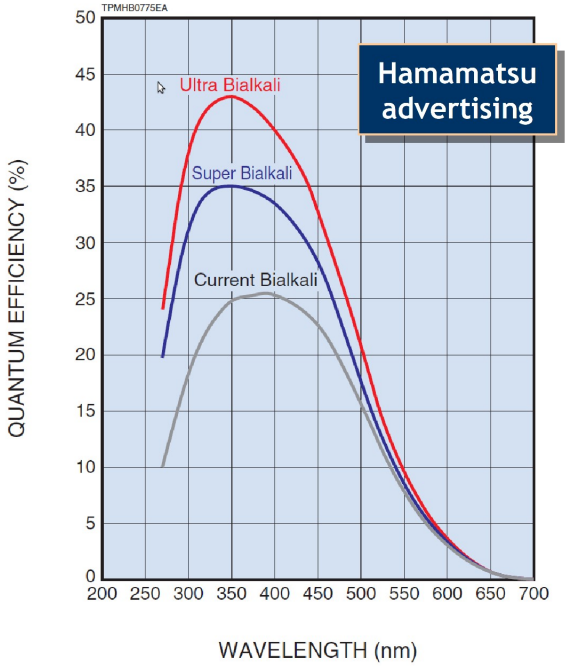
R8900

- Hamamatsu H8500C 64-channel PMA

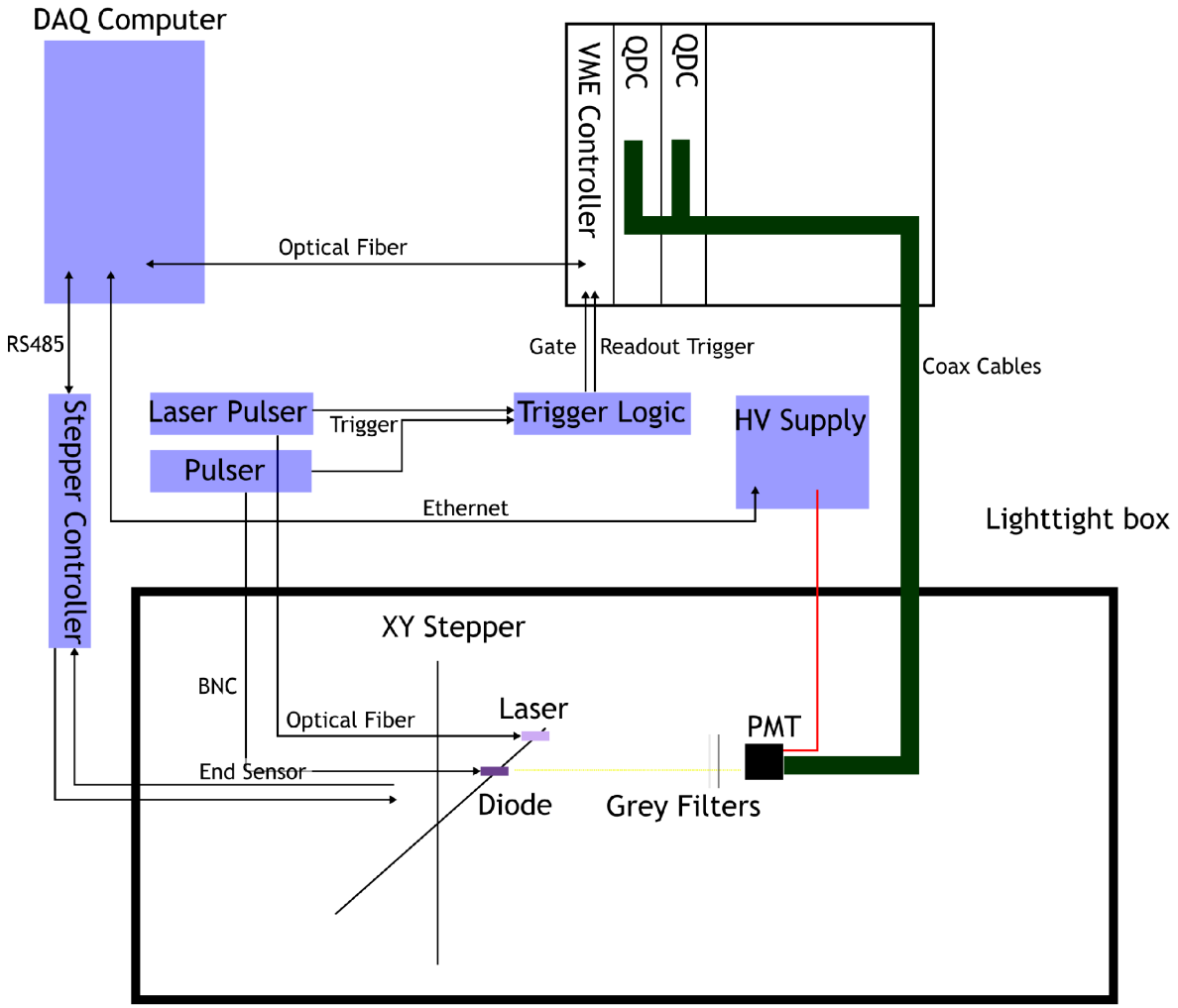
  still not available with super cathodes
  - active area 49x49mm² (89%)
  - Hamamatsu voltage divider

H8500C





PHOTOMULTIPLIERS - Gain & Uniformity



PHOTOMULTIPLIERS - Gain & Uniformity

[1] XY-stepper

[2] laser

[3] ND filters

[4] PMT

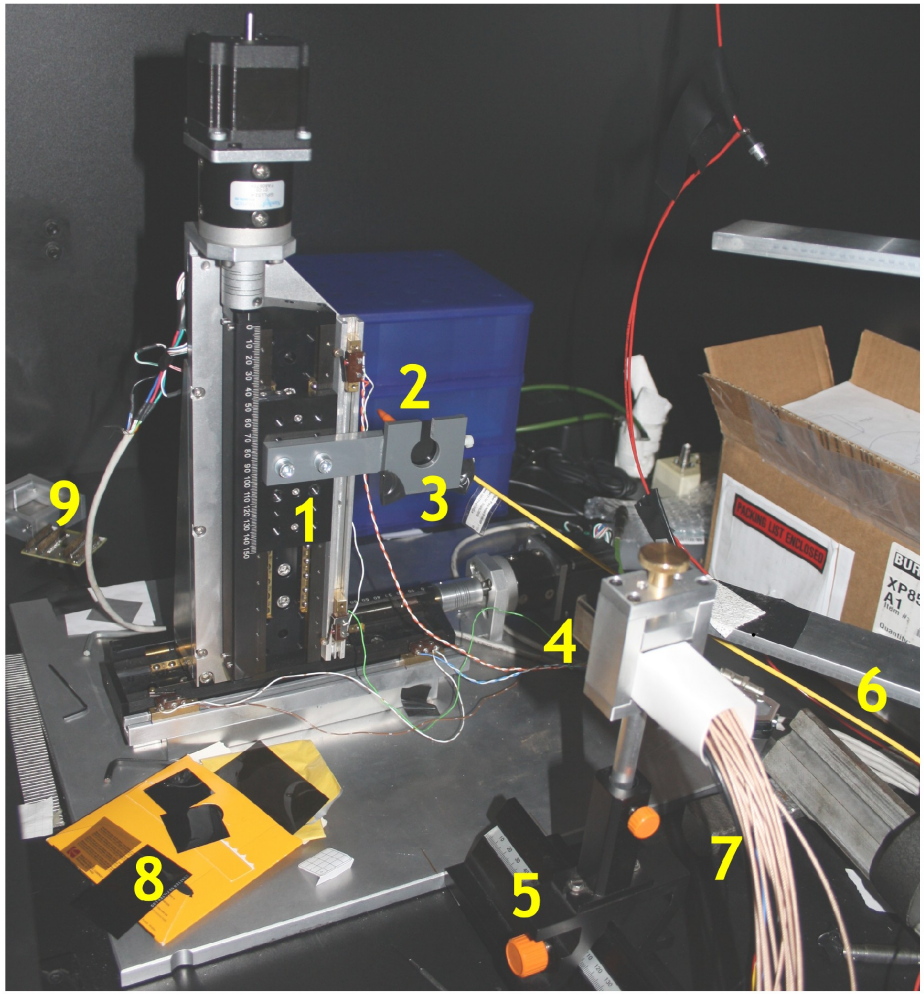
[5] optical bench

[6] optical fiber

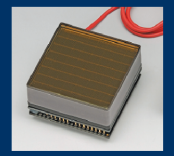
[7] cables to DAQ

[8] additional ND filters

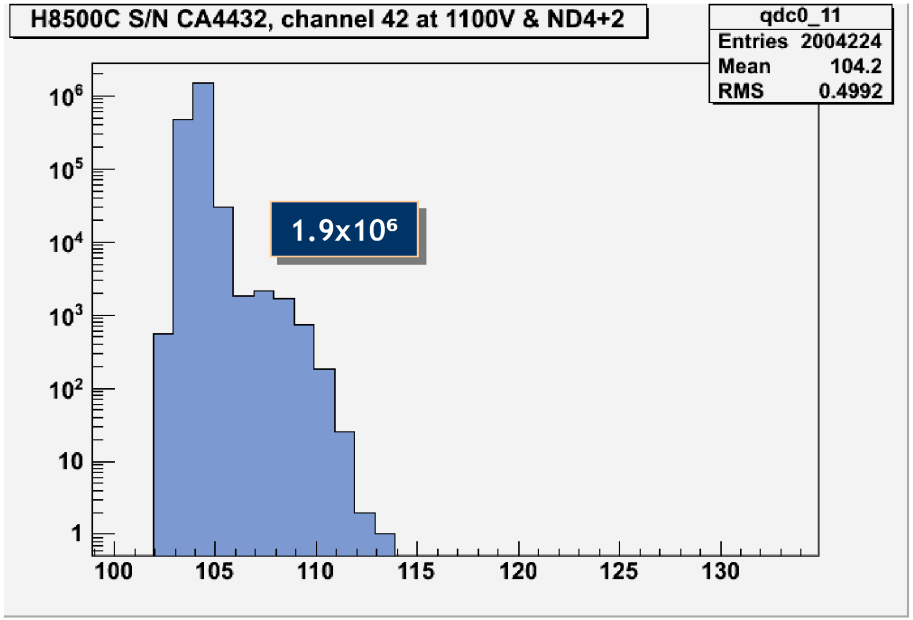
[9] additional adapters

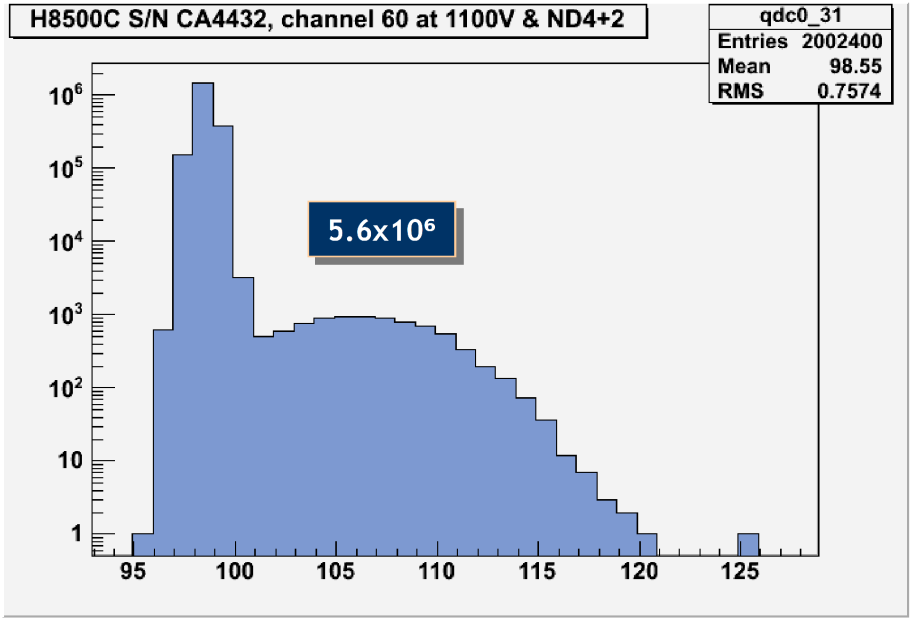


PHOTOMULTIPLIERS - Gain & Uniformity - H8500C

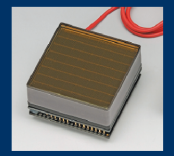


- QDC spectra for two channels of the same PMT @1100V
- 100fC/channel ≙ Gain of 0.625×10^6/Channel

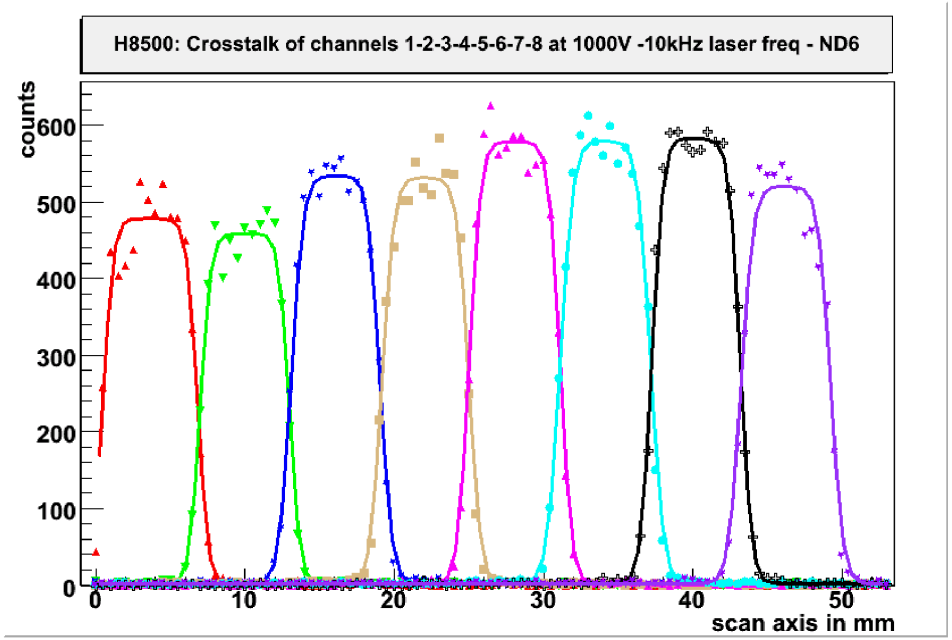


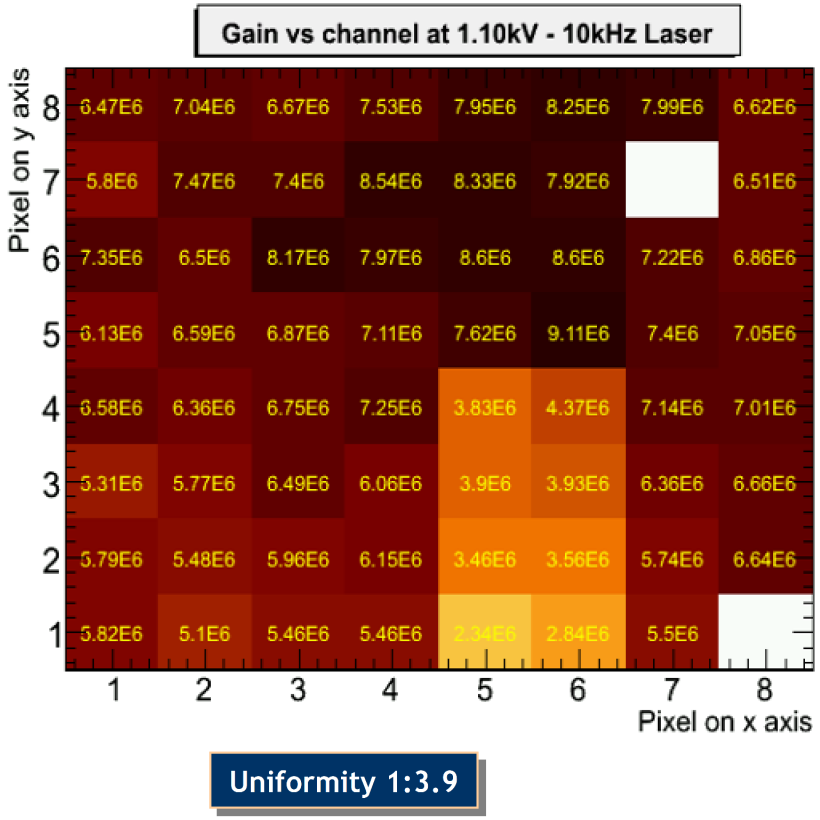


PHOTOMULTIPLIERS - Gain & Uniformity - H8500C



- Crosstalk and gain vs pixel

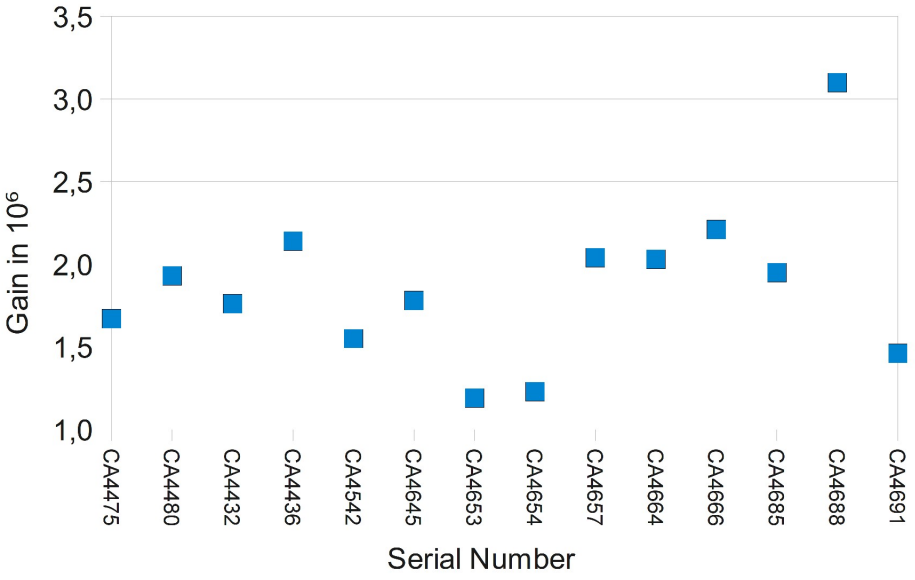


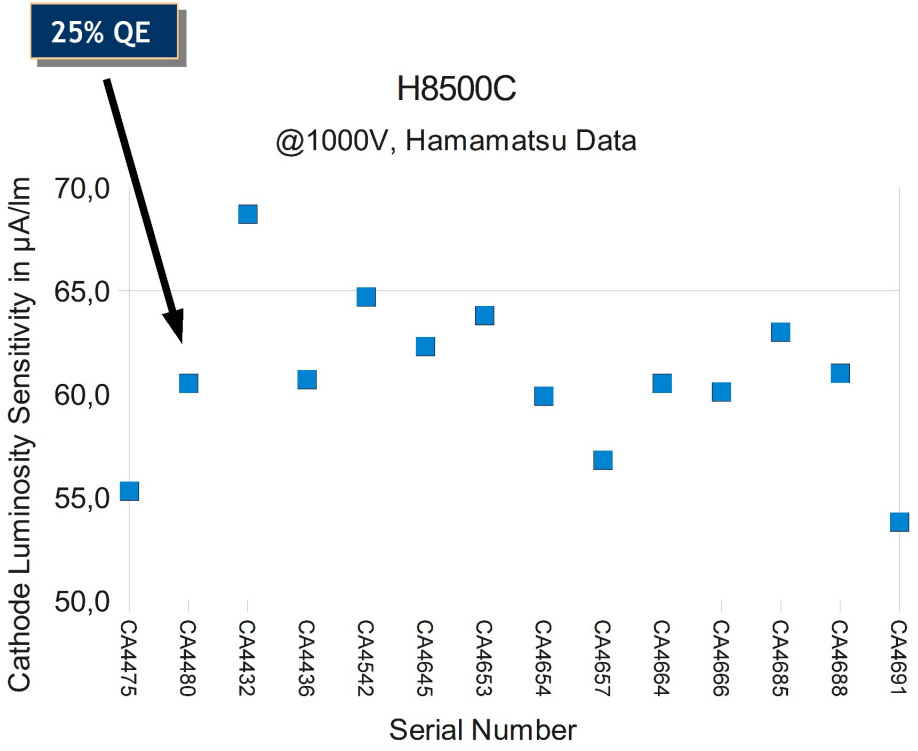


Uniformity 1:3.9

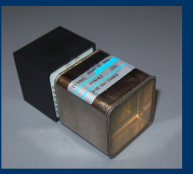
PHOTOMULTIPLIERS - Gain & Uniformity - H8500C

- Gain and luminosity sensitivity of several PMTs

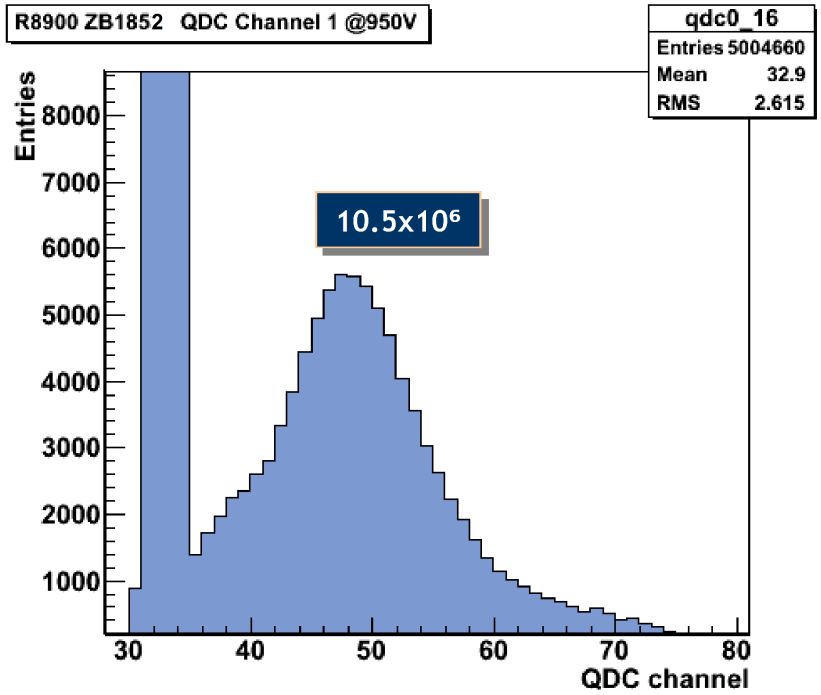




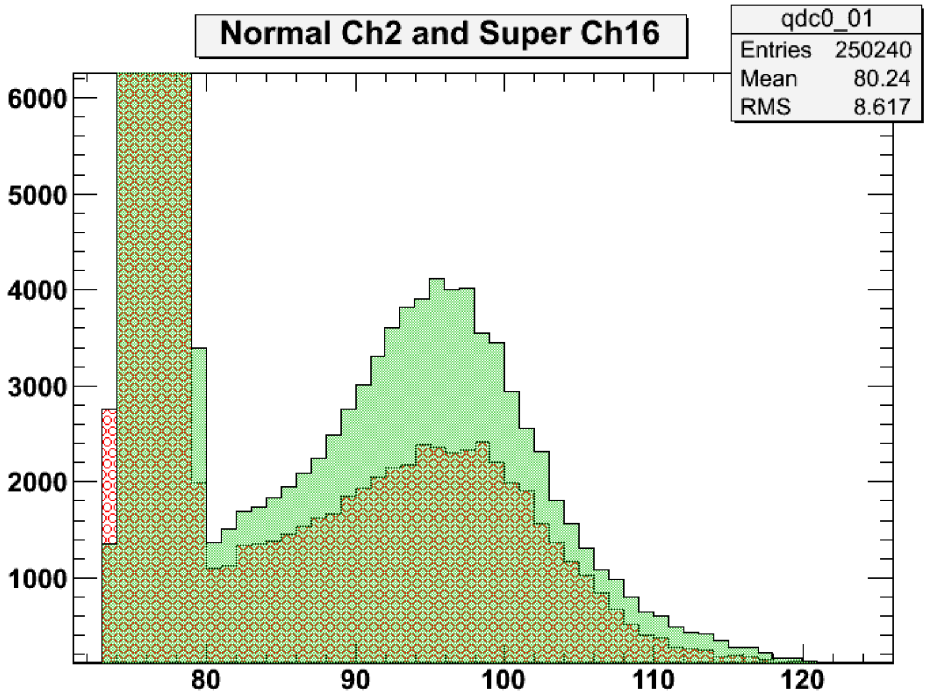
PHOTOMULTIPLIERS - Gain & Uniformity - R8900



- spectra of R8900 PMT @950V

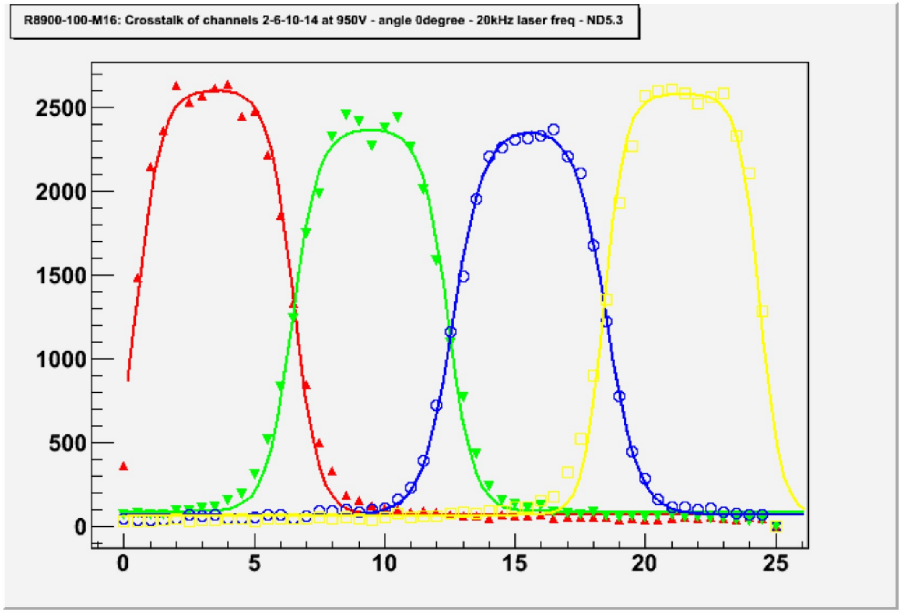


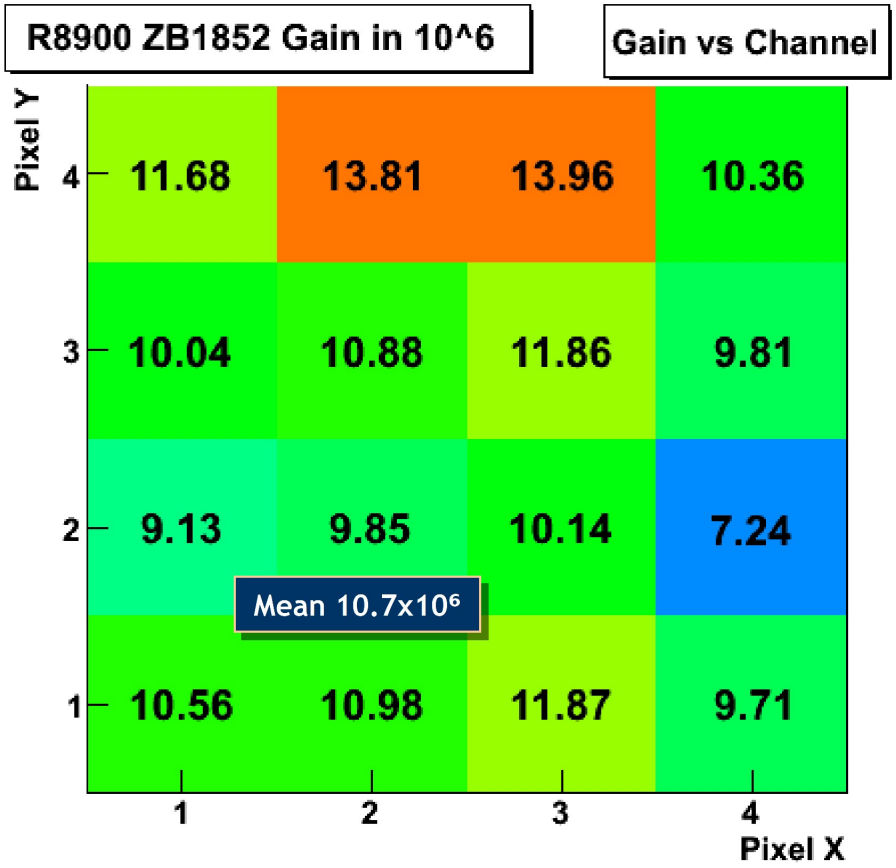
Comparison of two channels with same gain



PHOTOMULTIPLIERS - Gain & Uniformity - R8900

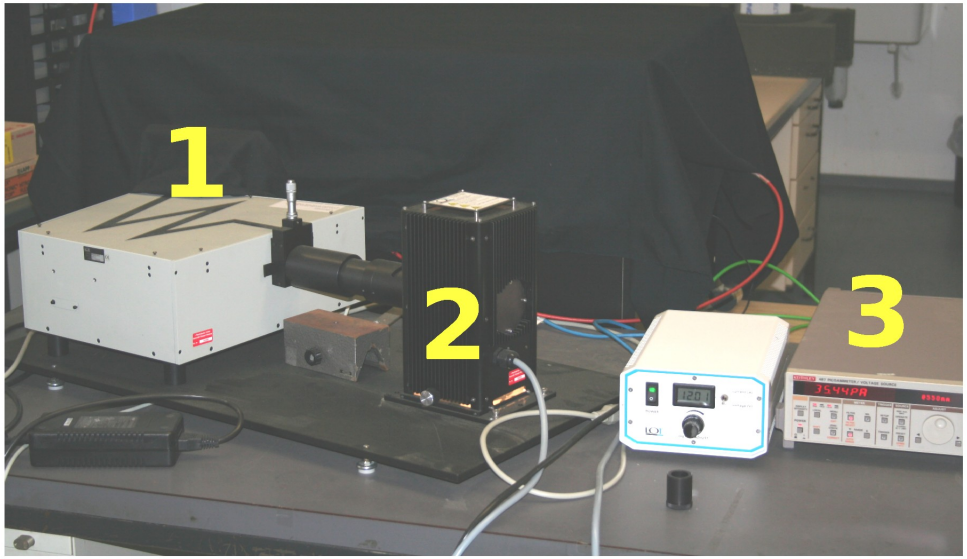
- Crosstalk and gain vs pixel @950V

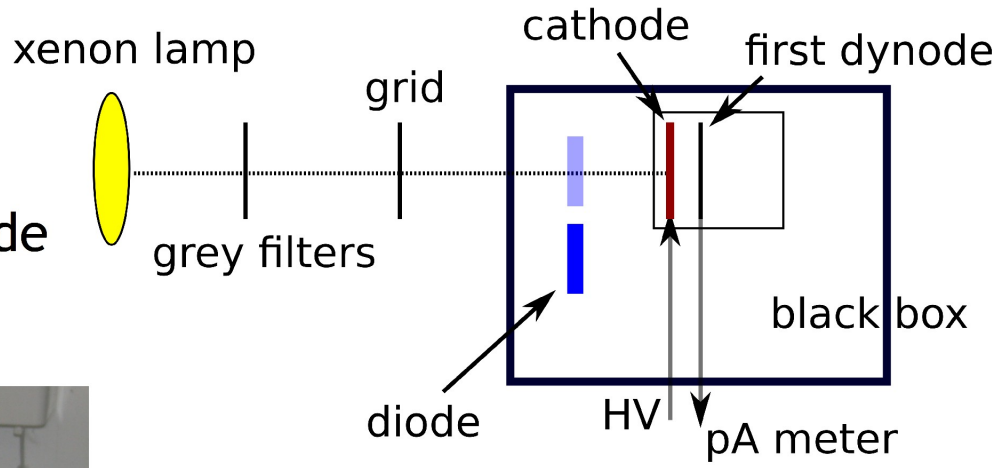




PHOTOMULTIPLIERS - QE Studies

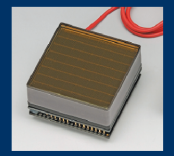
- Xenon Lamp (200-700nm) [2]
- Grid (Δλ=1nm) [1]
- Calibrated Hamamatsu photodiode
- Picoamperemeter [3]



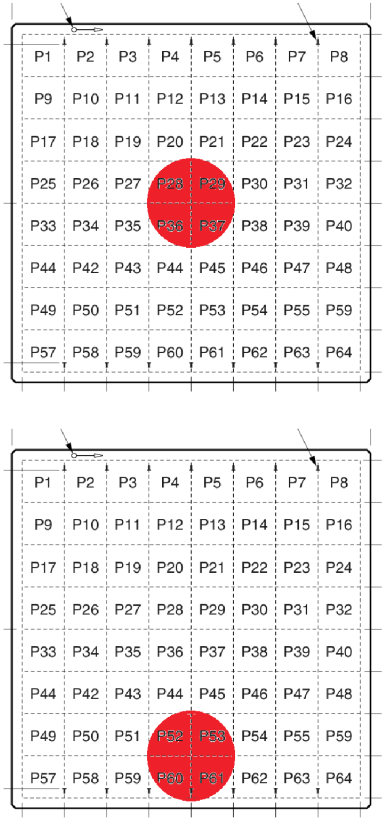


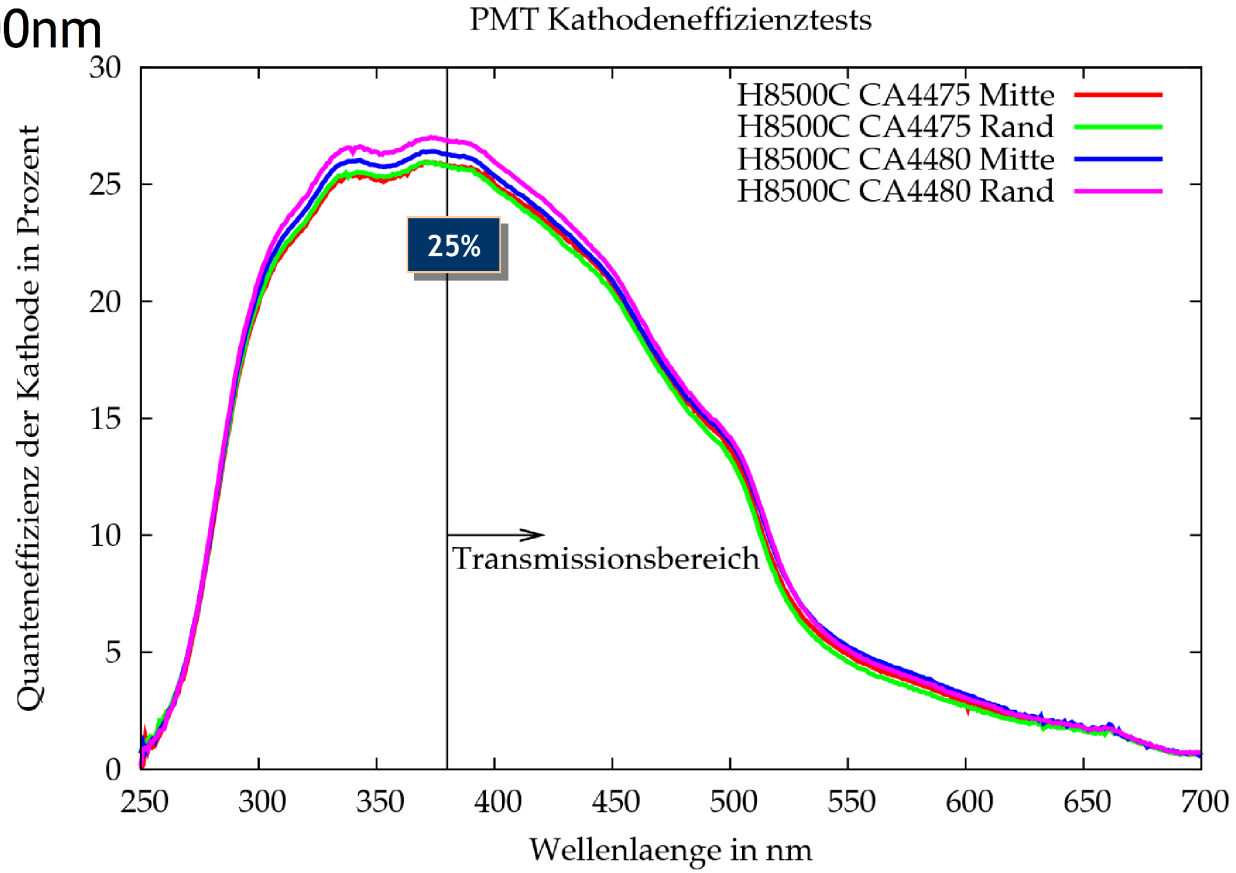
Math Lab based software
- incl. data acquisition
- driver for grid

PHOTOMULTIPLIERS - QE Studies



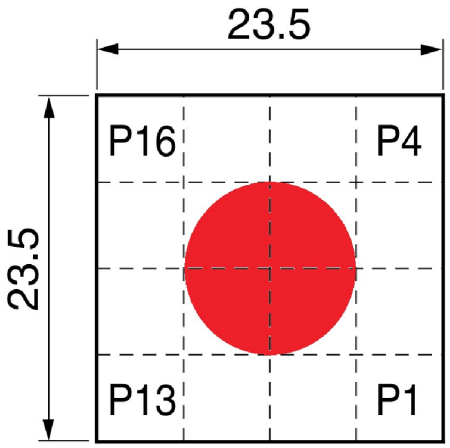
- H8500C
- absolute QE 25% at 400nm

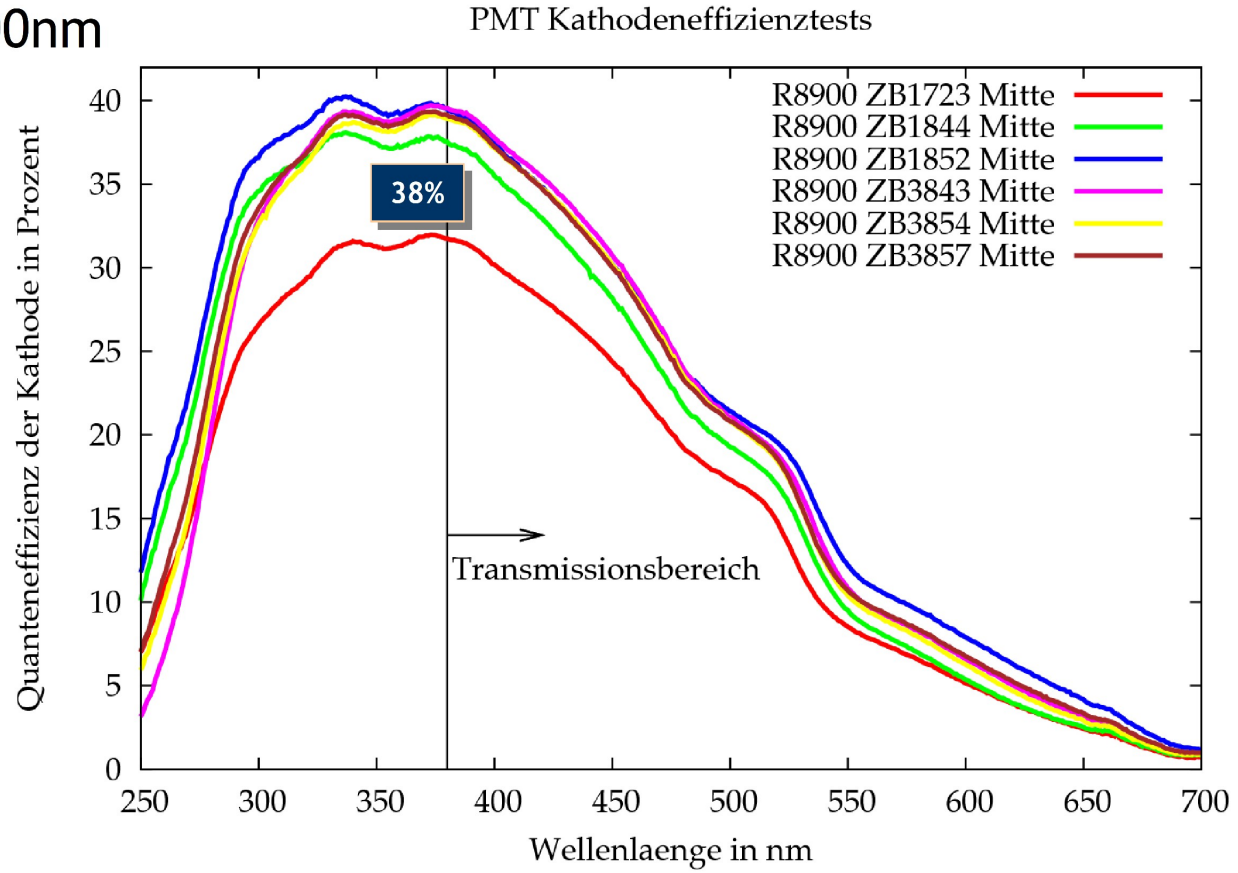




PHOTOMULTIPLIERS - QE Studies

- R8900-100-M16
- absolute QE 38% at 400nm



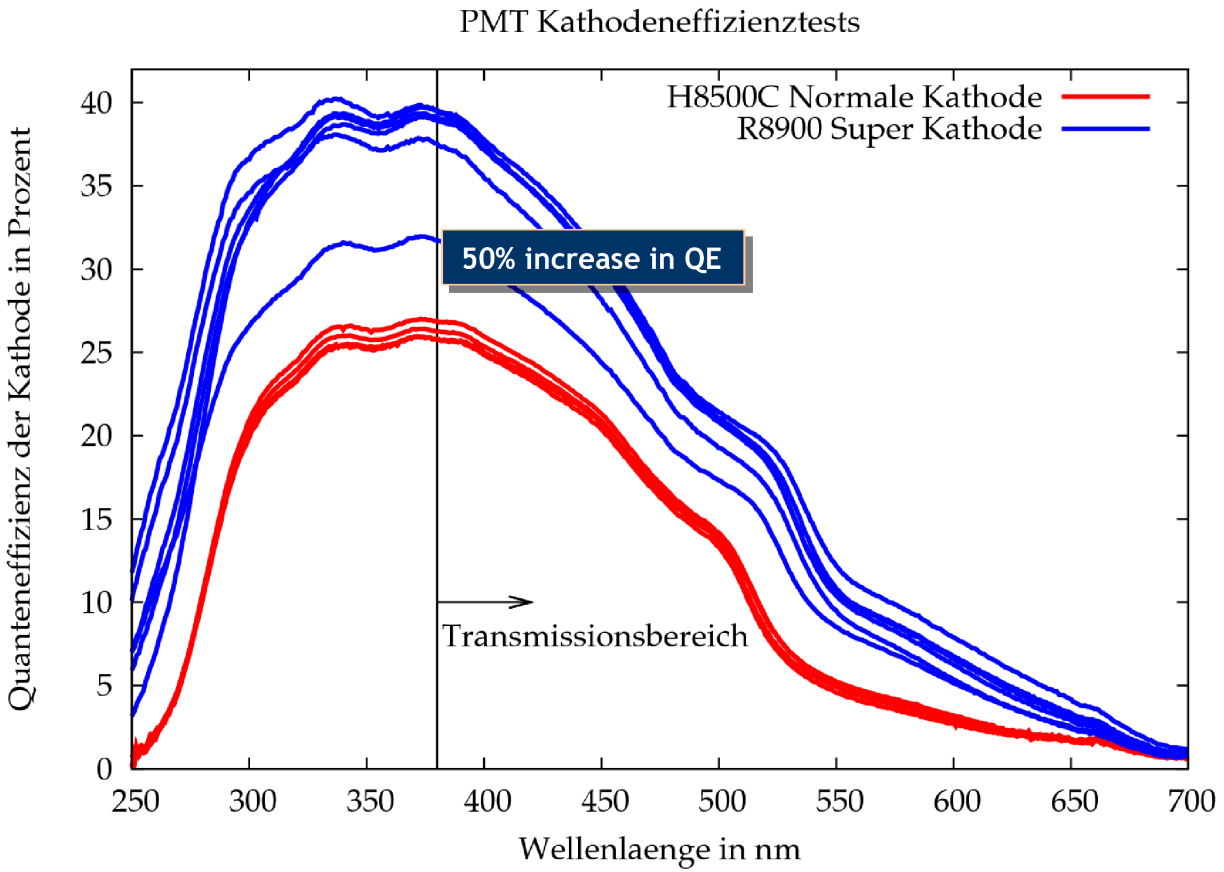


PHOTOMULTIPLIERS - QE Studies

- QE raised by 50%
- Detection efficiency even higher because of higher gain

  →

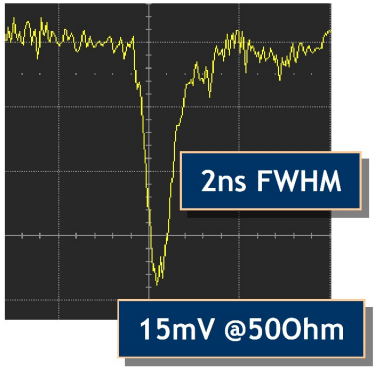
  Number of detected Photons raised by up to 70%



PHOTOMULTIPLIERES - Readout

FRONT END ELECTRONICS (ZEL Jülich)

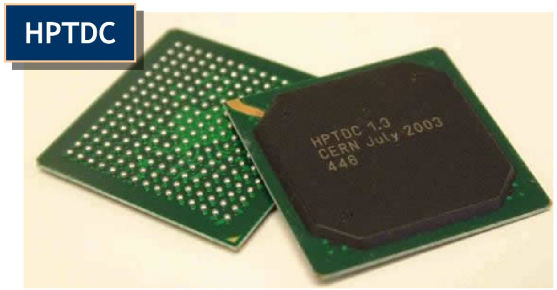
- Low signal: single photons @ Gain ~2x10^6 (10x10^6 with R8900)
  - ~500fC discriminator threshold
- Low uniformity (4:1 with H8500C, 2:1 with R8900)
  - We got 6 H8500C tubes with low gain (~1.5x10^6) but good uniformity (<2:1)
- Integrated solution Maroc 3
  - 64 channel individual adjustable preamp
  - common threshold discriminator
    - 10 fC – 5000 fC
  - integrated ADC with multiplexer



Maroc 3

PHOTOMULTIPLIERS - Readout

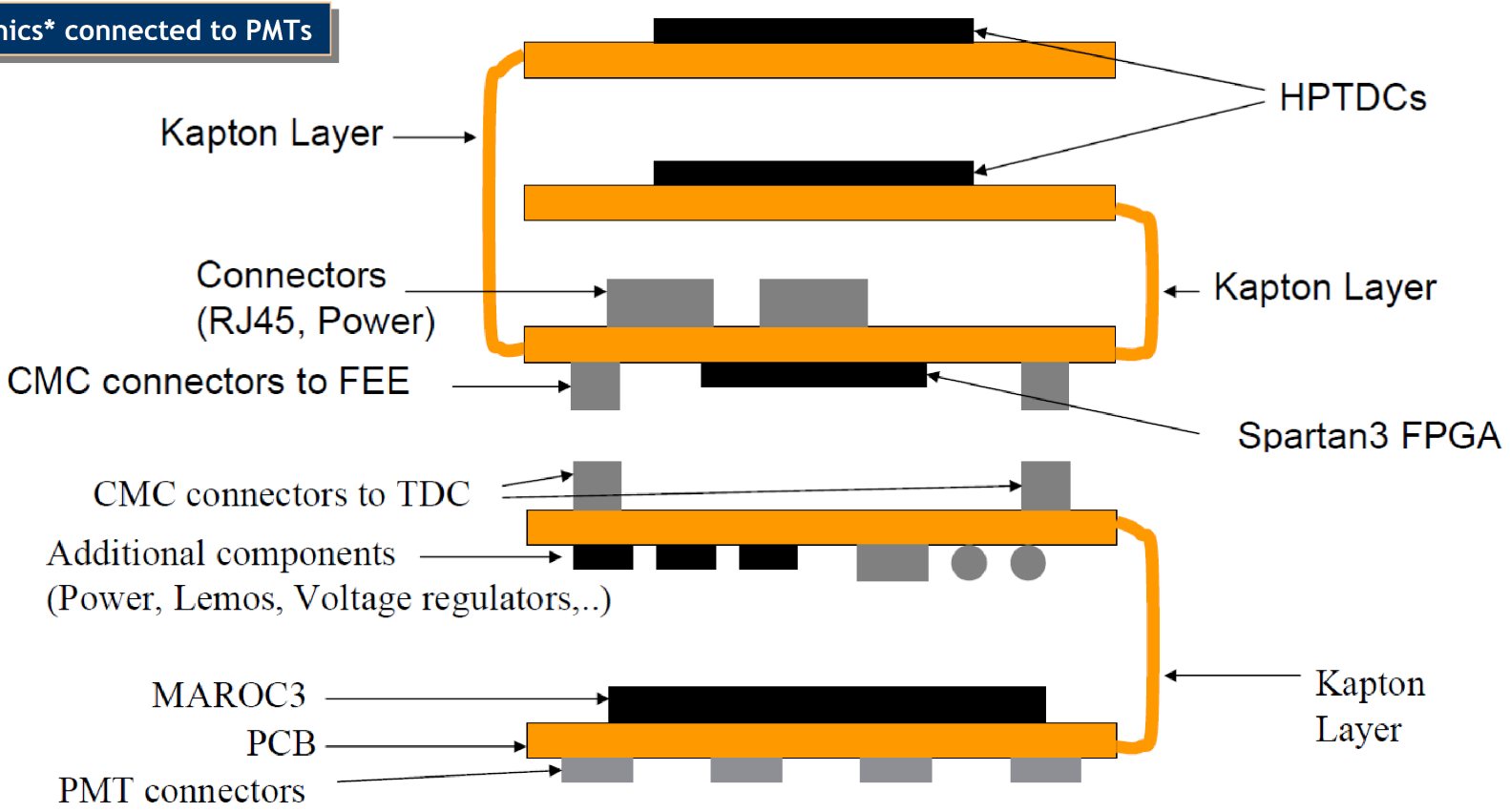
DAQ ELECTRONICS



- ca. 8000 channels, WASA TDCs expensive
- HPTDCs from CERN
  - 32 channels
  - Time resolution 65ps (RMS)
  - Dynamic range 20bit
- Integration into WASA DAQ with Spartan 3 FPGA Board
  - Distributing timing information (START and CLOCK)
  - Send and receive serial data
- For beam tests use existing TOF DAQ (abandoned hodoscope)

PHOTOMULTIPLIERS - Readout

Electronics* connected to PMTs



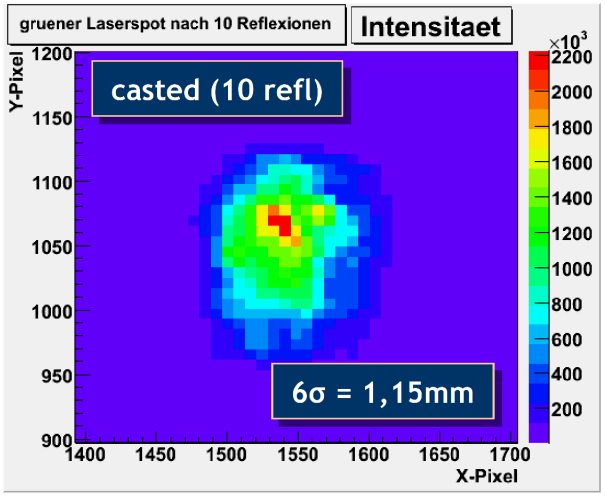
*by Harald Kleines - ZEL Jülich

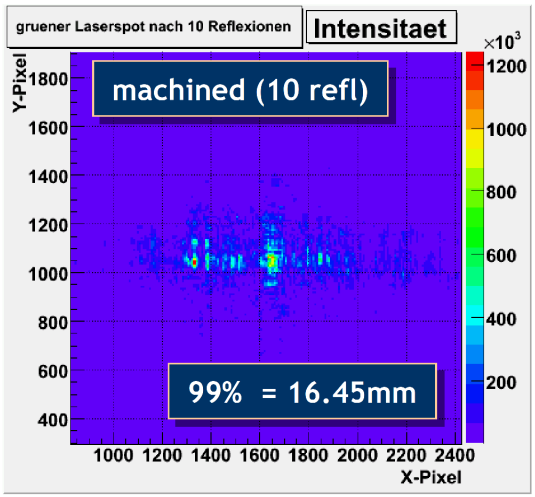
RADIATORS AND OPTICS - Surface Studies

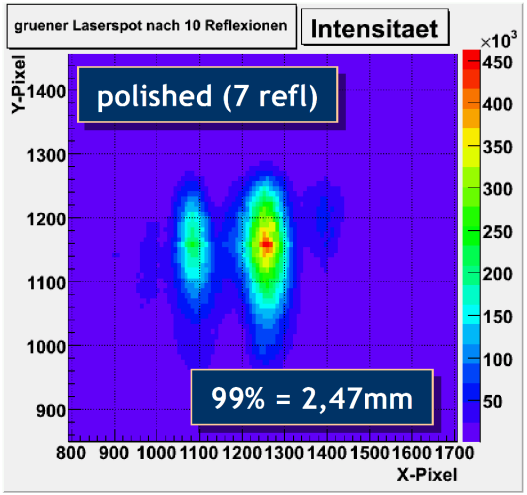
- Measurement of reflectance with laser and photo-diodes

Surface treatment	Reflectance
machined	92-98%
polished	98.5%
casted	99.0%

- Photon diffusion and scattering tested with laser and CMOS camera

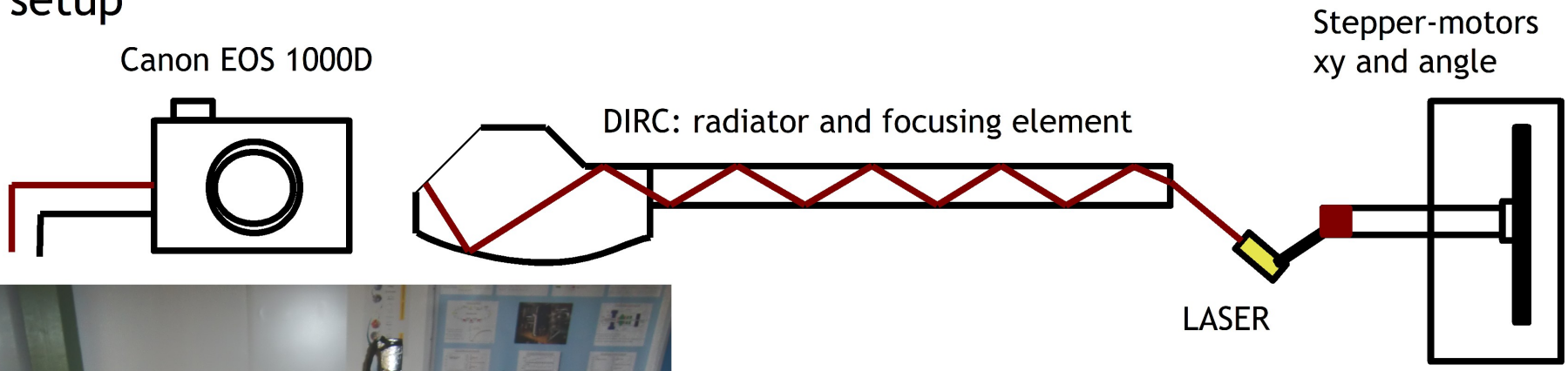






RADIATORS AND OPTICS – Focusing Properties

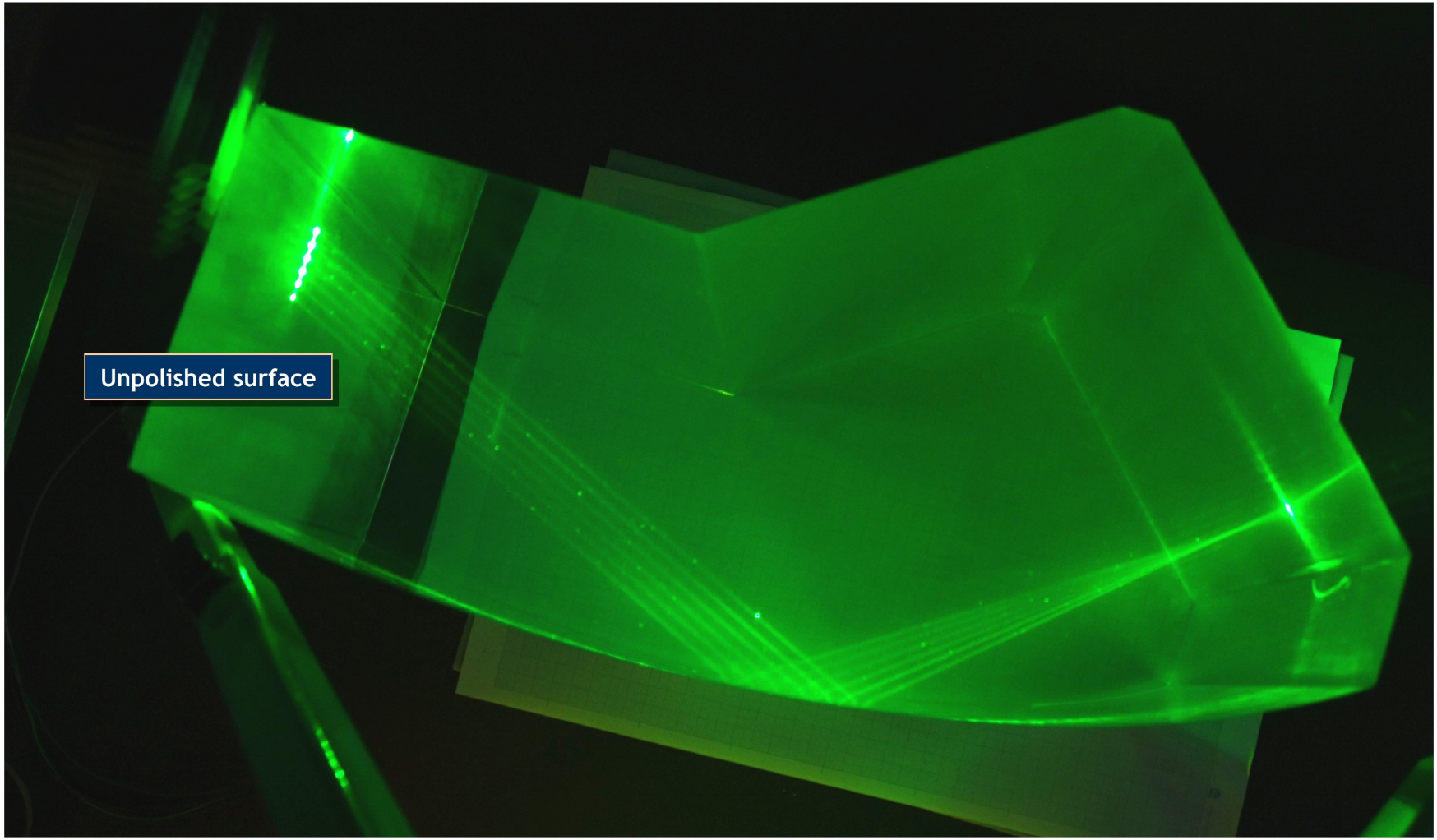
- setup



1. Camera
2./4. Stepper controller
3. Laser power supply
5. Stepper with laser
6. Focussing element

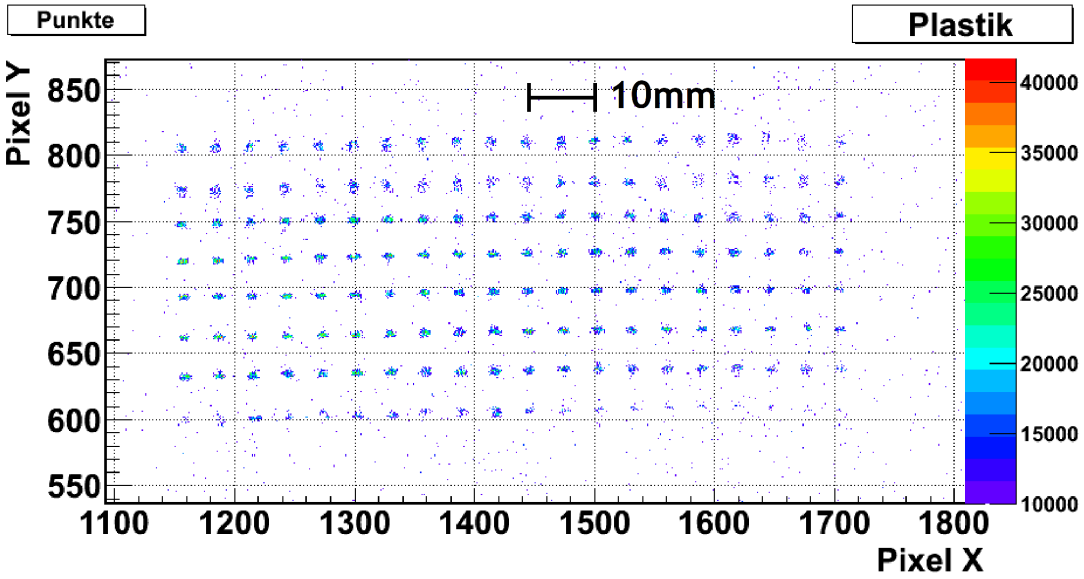
- step-width: 0.0075mm/0.9°
- range: 400x400mm²/0-180°
- laser: λ=635nm and 532nm
- resolution: ca. 10 pixels/mm

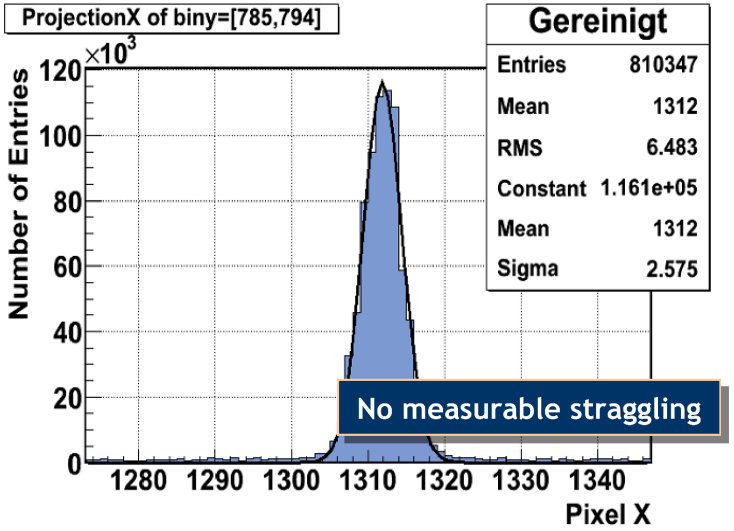
RADIATORS AND OPTICS – Focusing Properties



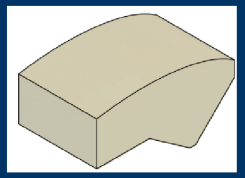
RADIATORS AND OPTICS - Focusing Properties

- One incident angle, several incident points, laser spot on screen after 10 reflections and transmission trough radiator

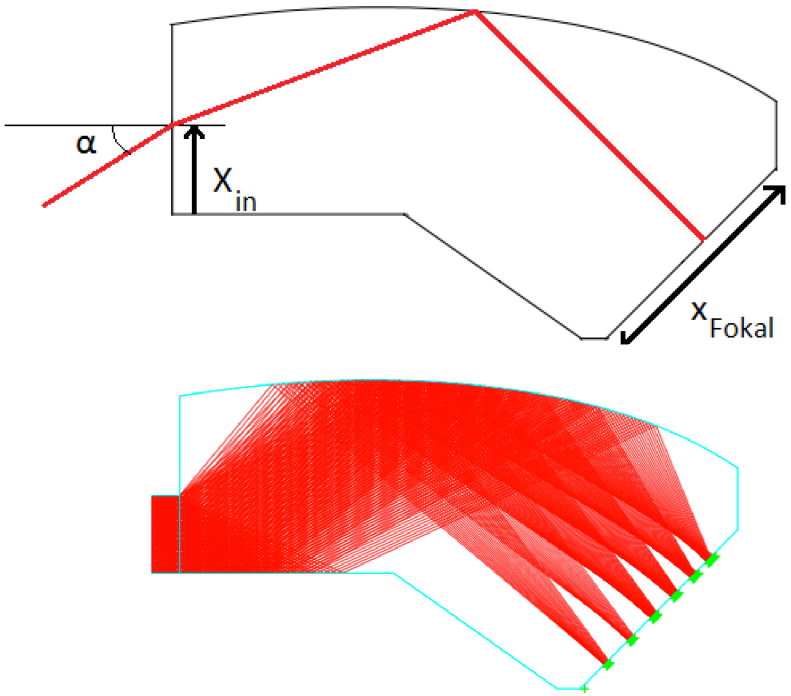


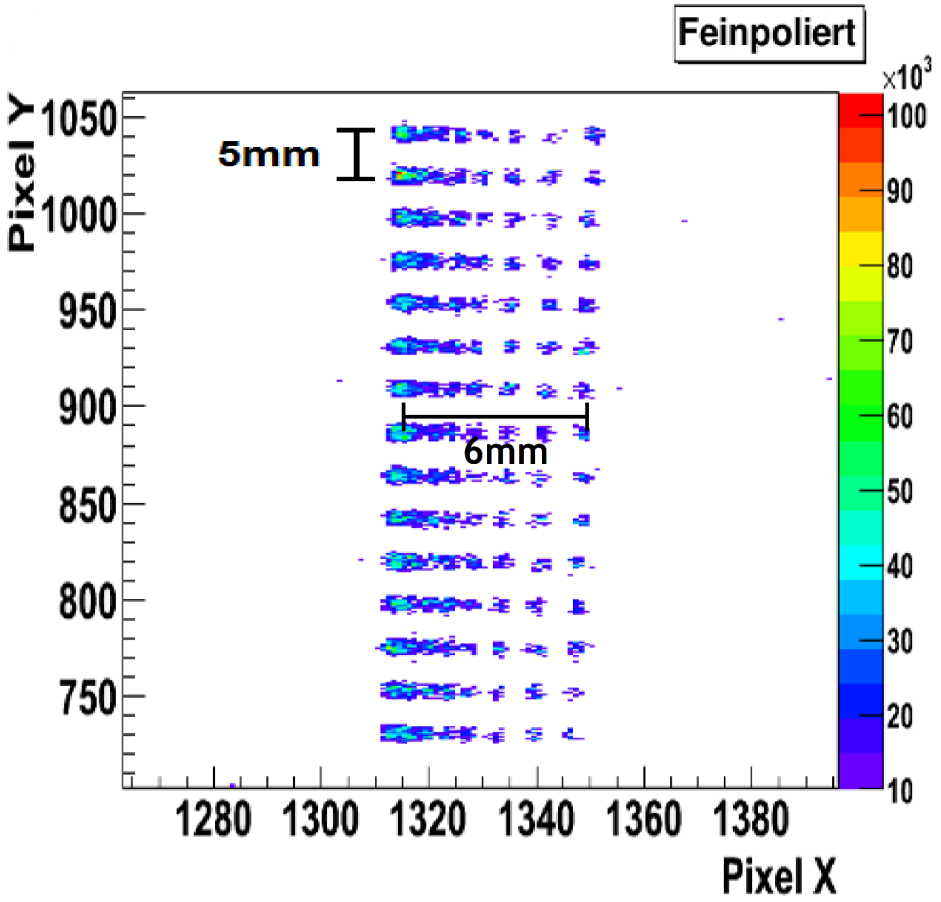


RADIATORS AND OPTICS - Focusing Properties



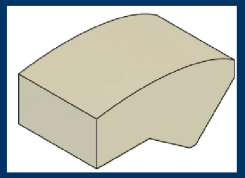
- One incident angle, several incident points (x and y)



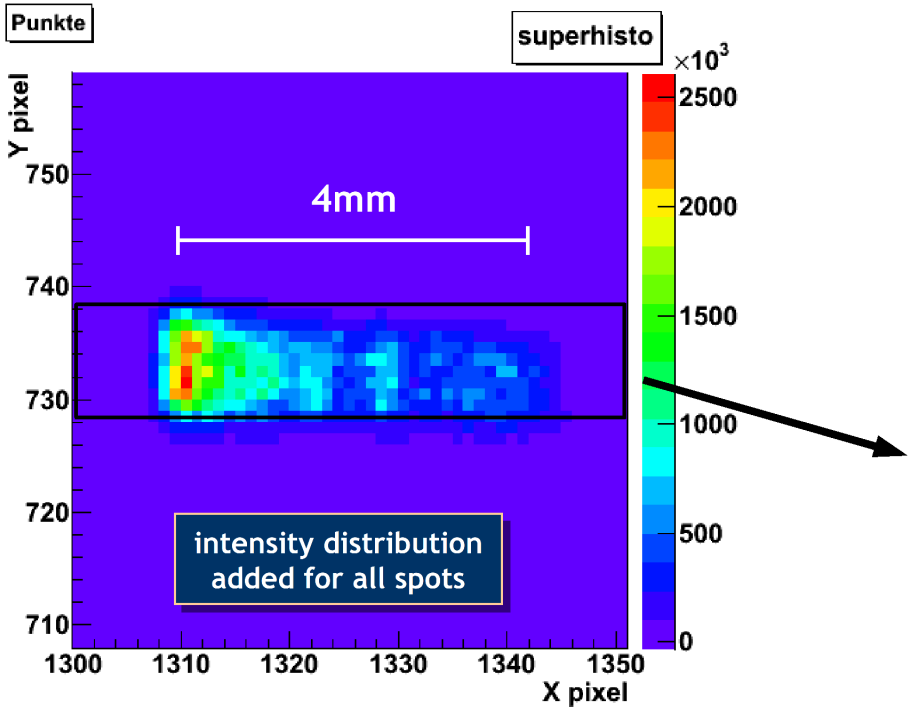


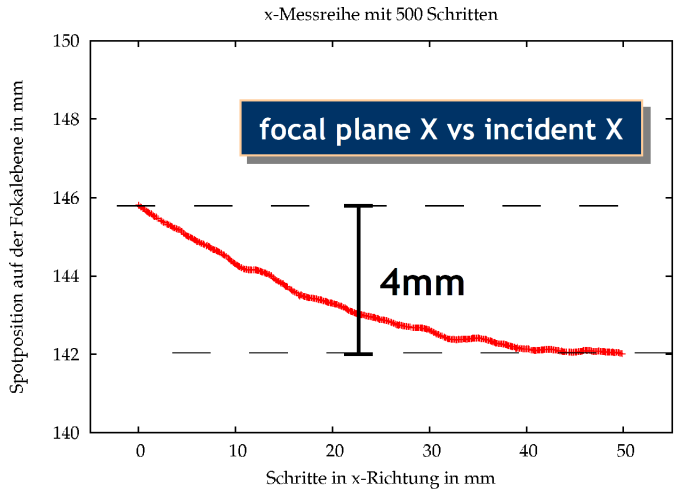
WASA-at-COSY

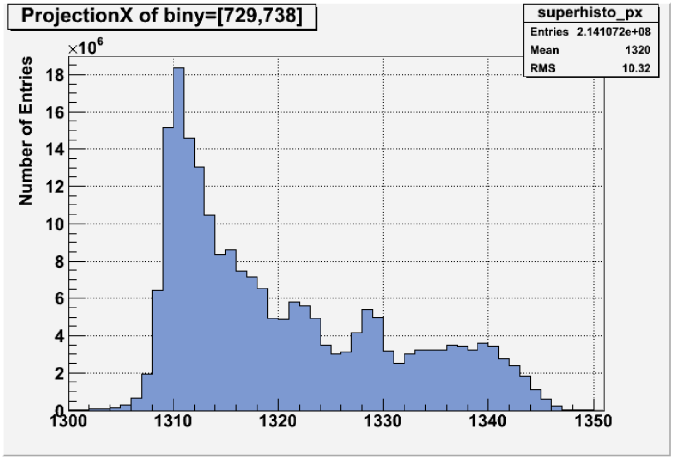
RADIATORS AND OPTICS - Focusing Properties



- Single line scan with more steps
  - 500 steps
  - 40° incident angle







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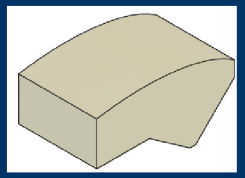
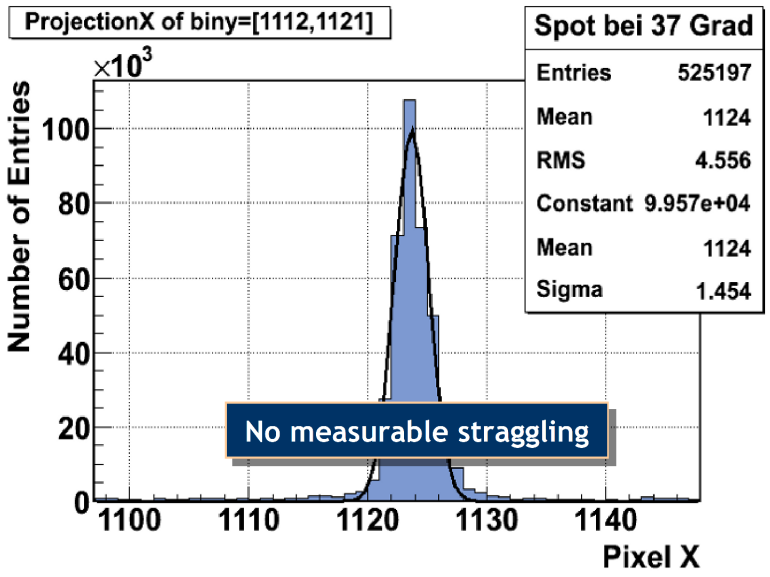
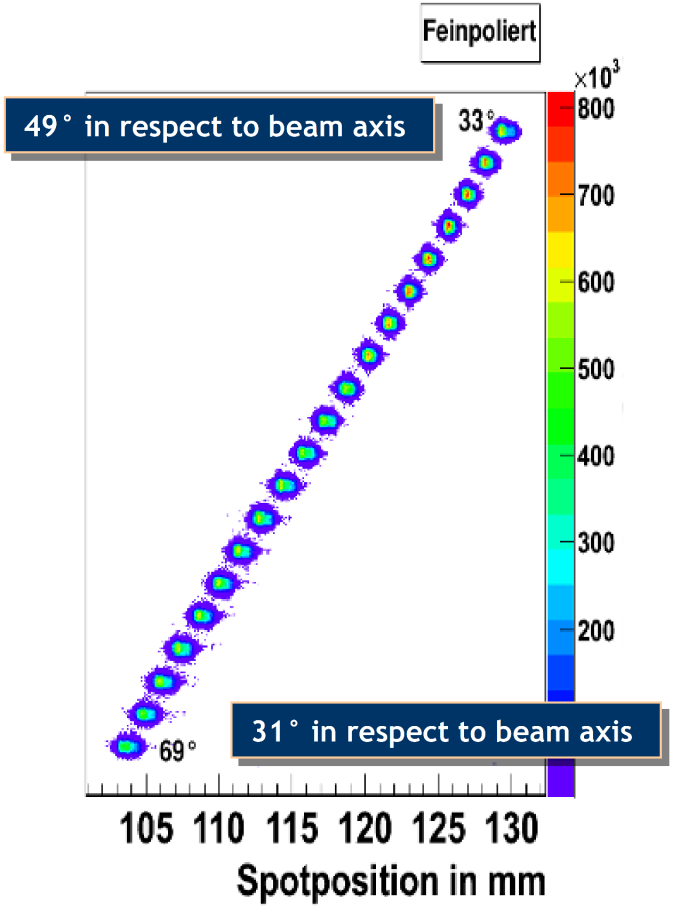


- several incident angle, several incident points (x), one y





WASA-at-COSY

TIMELINE, SUMMARY & OUTLOOK

- FoEl and radiator are manufactured and exceed expectation
  - Assembly of prototype is ongoing
- R8900 PMTs will raise number of detected photons by 1.5 and increase signal/noise at higher costs
- For prototypes: 14 H8500C and 12 R8900 delivered, 2 H10966-100 ordered. The rest equipped with H6568
- Prototype ready for testing at end of may
- DAQ and electronics check at TOF areal
- Tomorrow 9.50h: “Mechanical Design of the WASA DIRC” - Evgueny Doroshkevich

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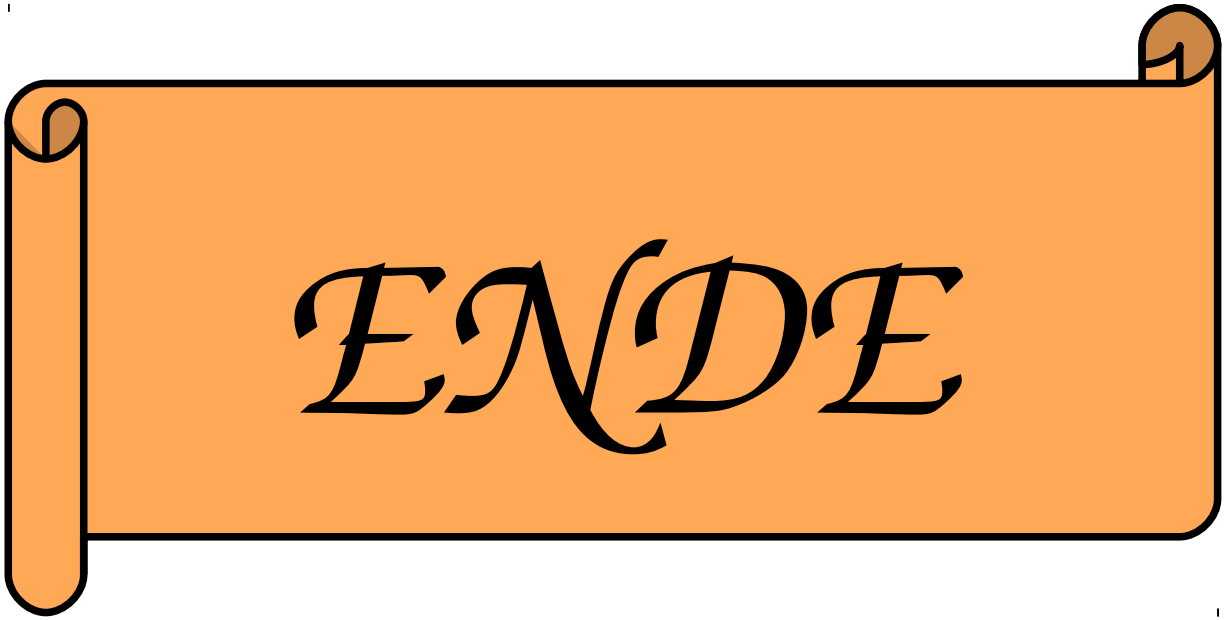
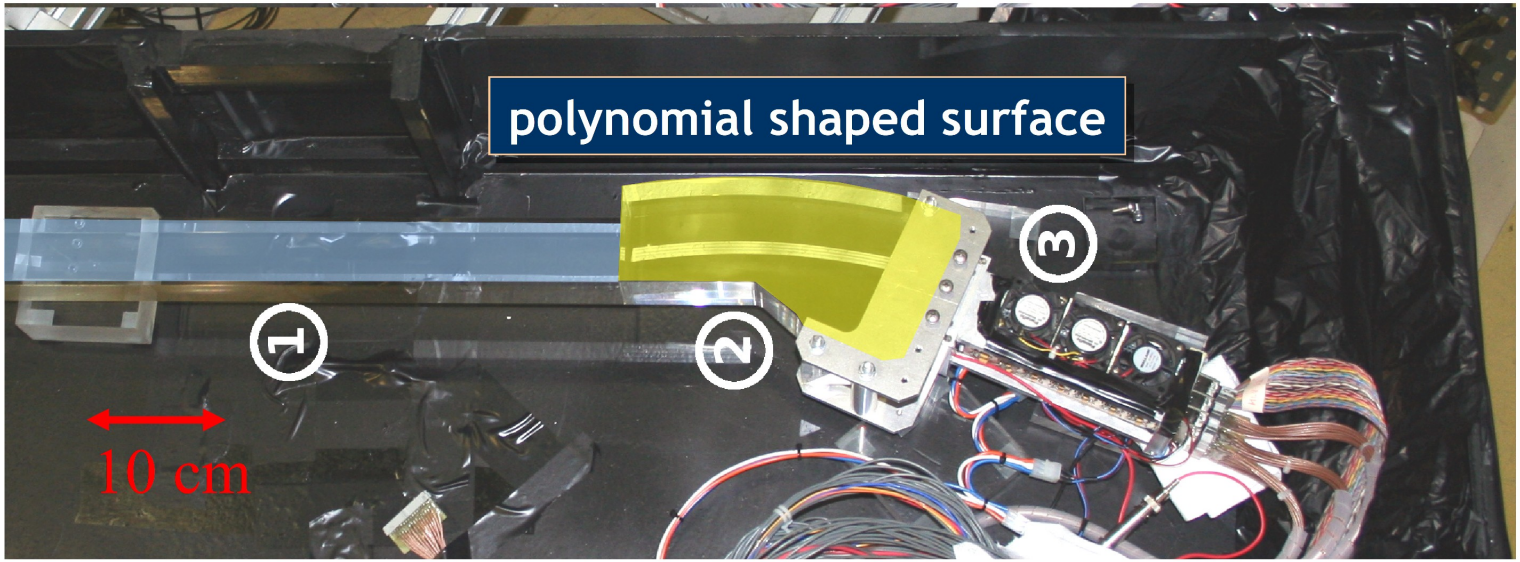
Thank you for your attention

LAST BUT NOT LEAST



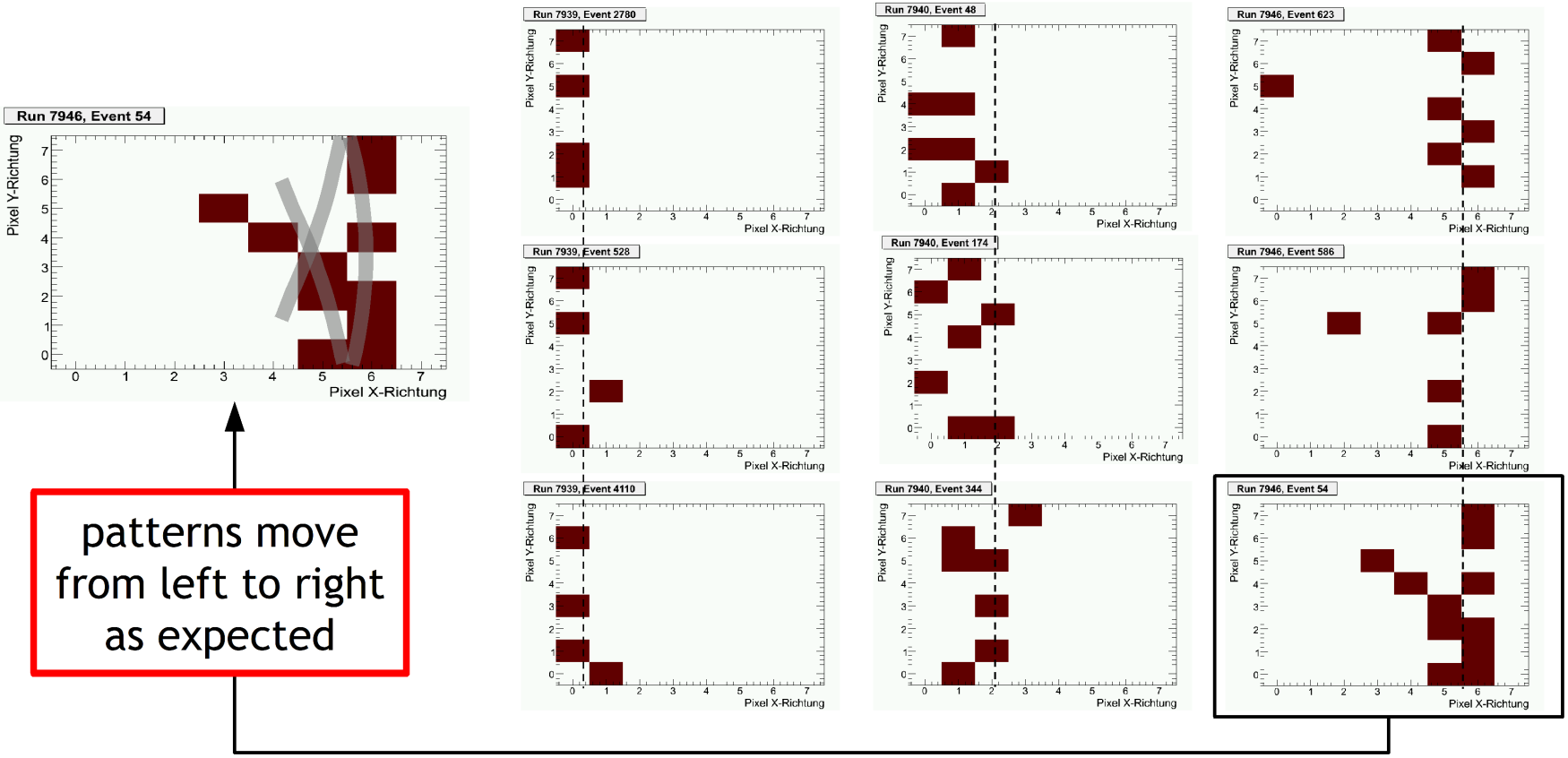
DIRC TESTS - internal reflecting

- prototype with internally reflecting optics optics
  1 radiator bar (Jülich, 40x40x600mm^3)
  2 focussing element (designed by Klaus Föhl)
  3 MAPMT readout(1 Hamamatsu H8500C)



DIRC TESTS - internal reflecting

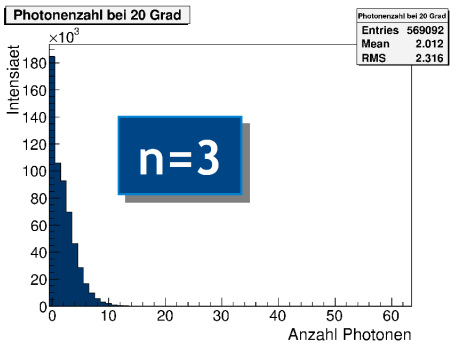
- Single event pictures for 20°, 25° and 35°

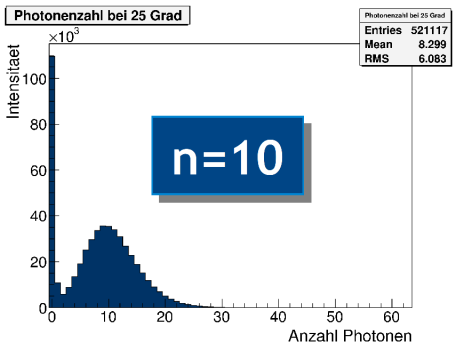


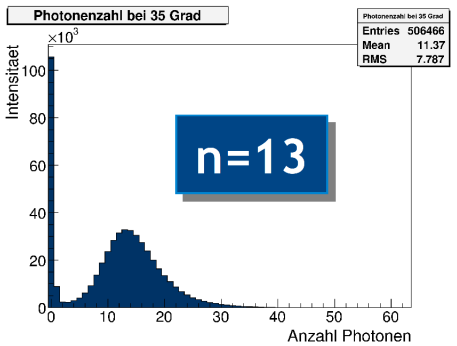
WASA-at-COSY

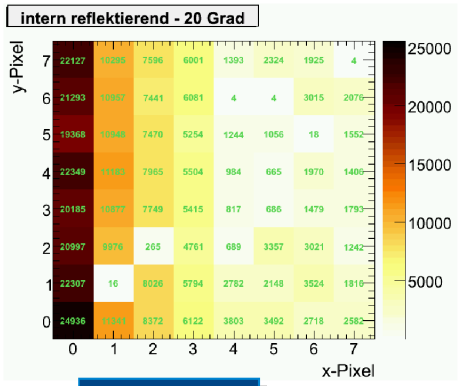
DIRC TESTS - internal reflecting

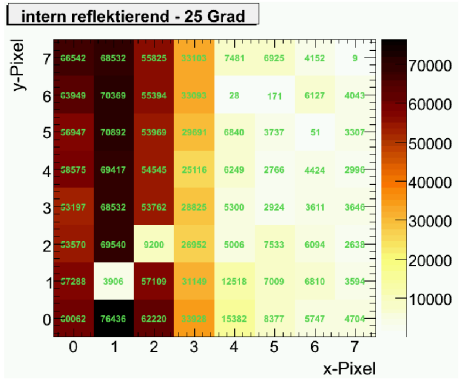
- internal reflecting optics, pattern and number of photons

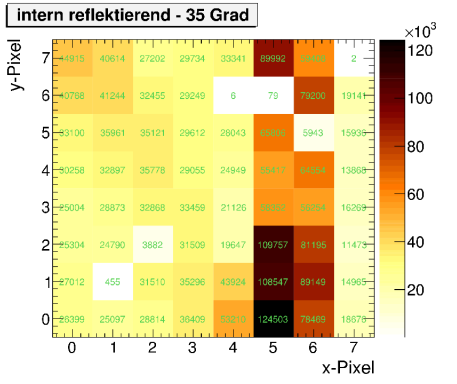








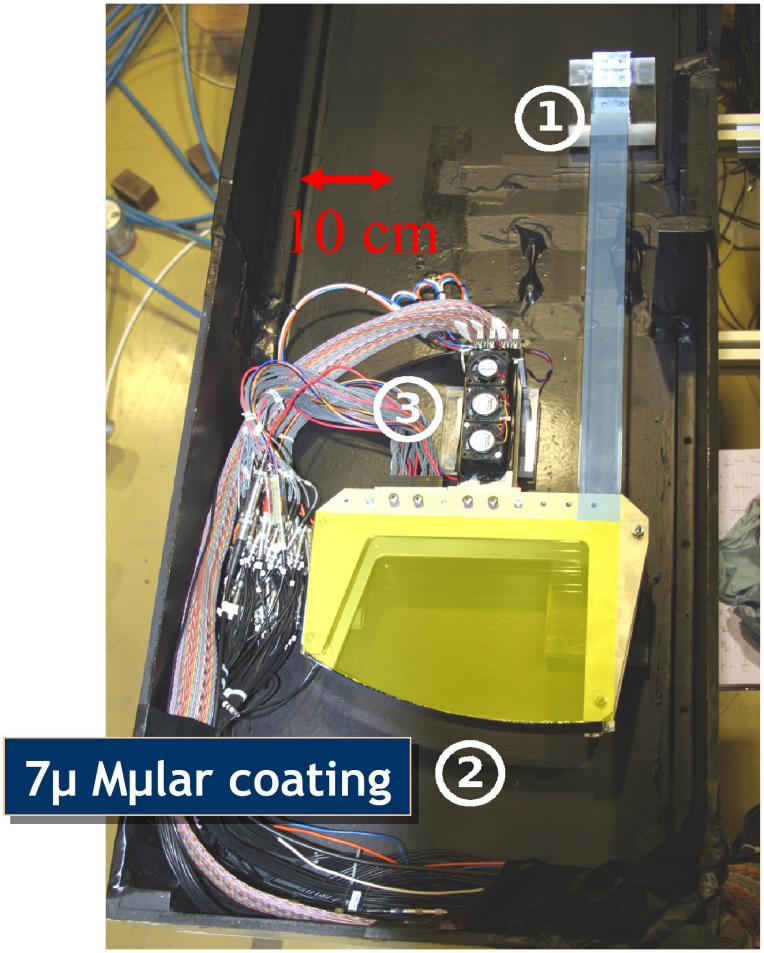




WASA-at-COSY

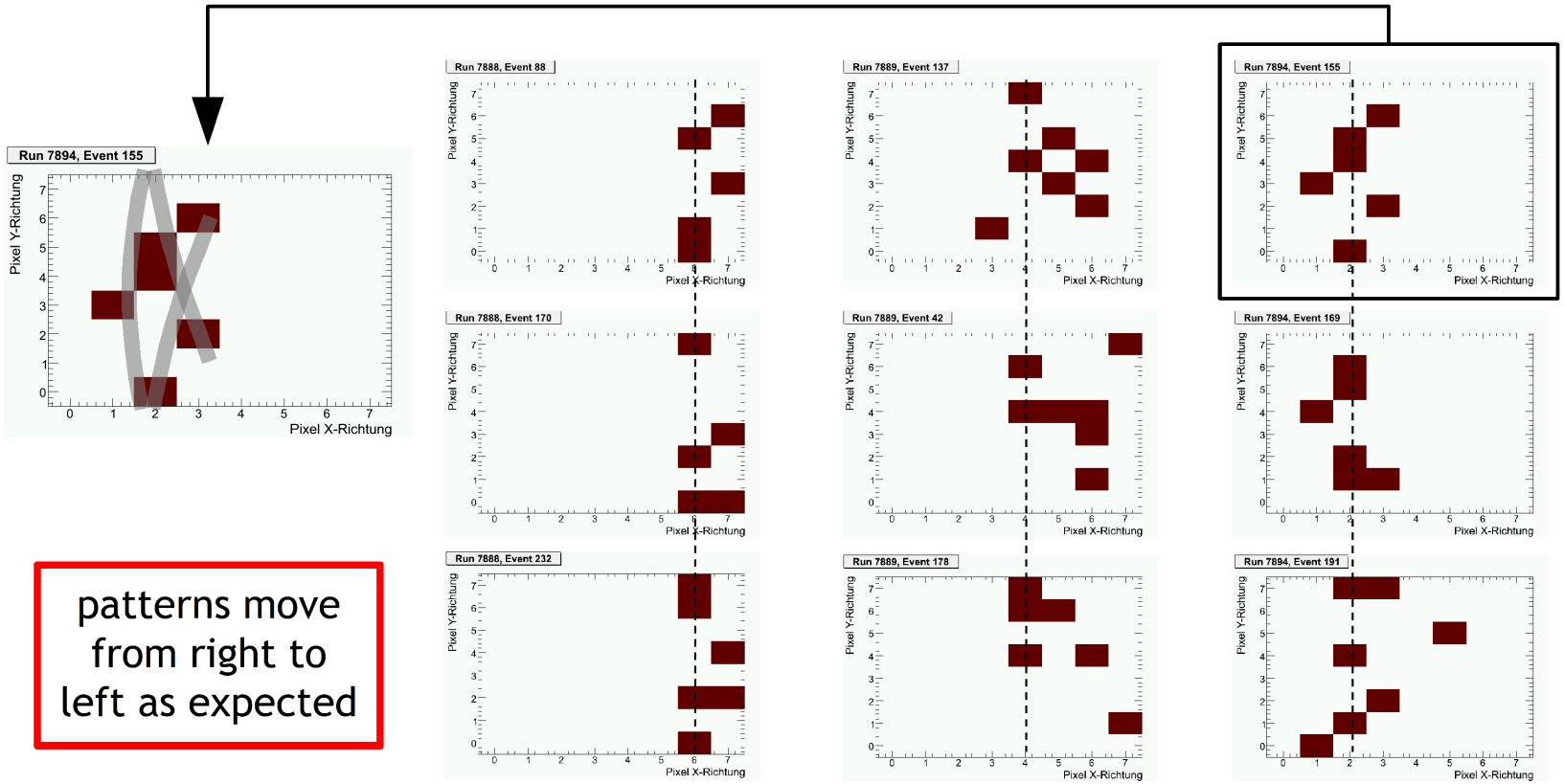
DIRC TESTS - mirrored optics

- prototype with mirrored optics
  1 radiator bar
    (Tübingen, 40x40x600mm^3)
  2 focussing element
    (designed by Regina Siudak)
  3 MAPMT readout
    (1 Hamamatsu H8500C)



DIRC TESTS - mirrored optics

- Single event pictures for 20°, 25° and 30°

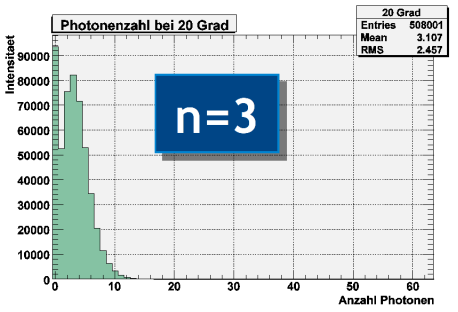


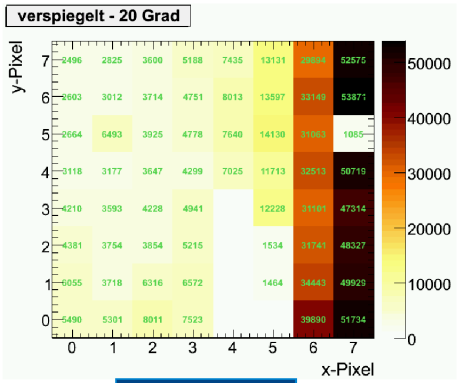
patterns move from right to left as expected

WASA-at-COSY

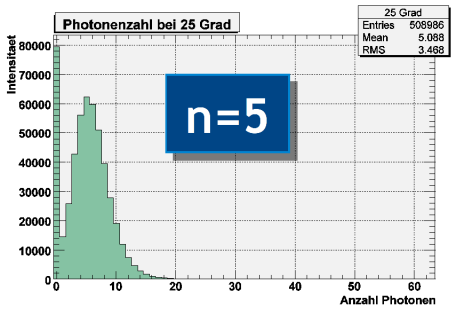
DIRC TESTS - mirrored optics

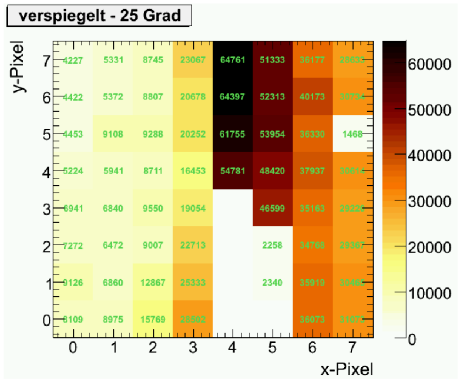
- mirrored optics, pattern and number of photons



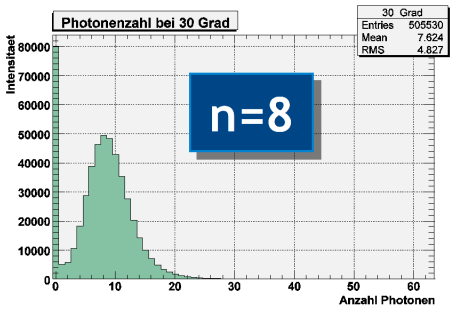


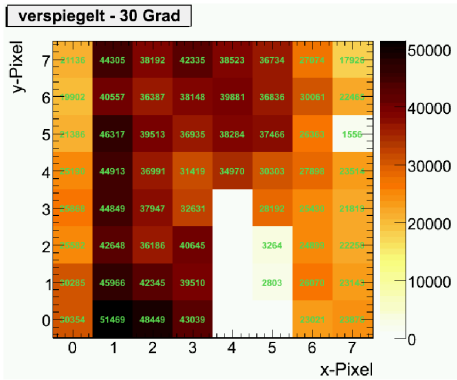
ϕ=20°





ϕ=25°





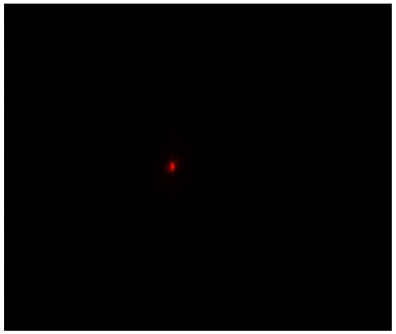
ϕ=30°

Laboratory DAQ

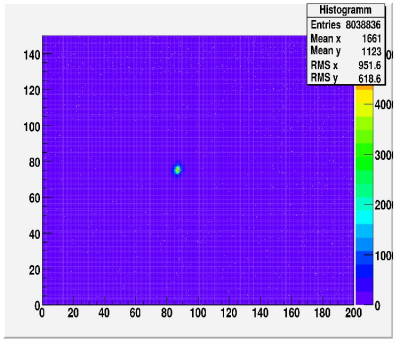
CR2-to-ROOT procedure

- CR2 → pgm (portable grey map, ADC value of each pixel) → root histo

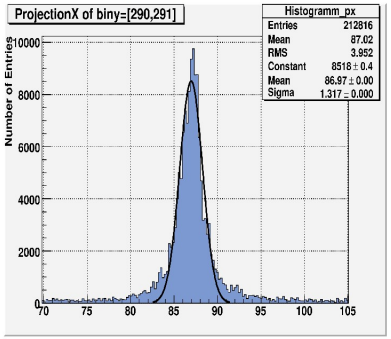
original CR2-image



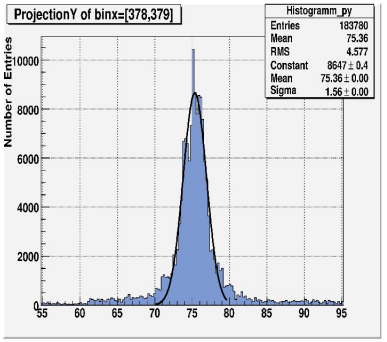
root-histogram

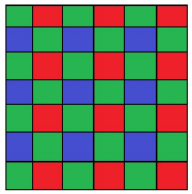


X-projection



Y-projection

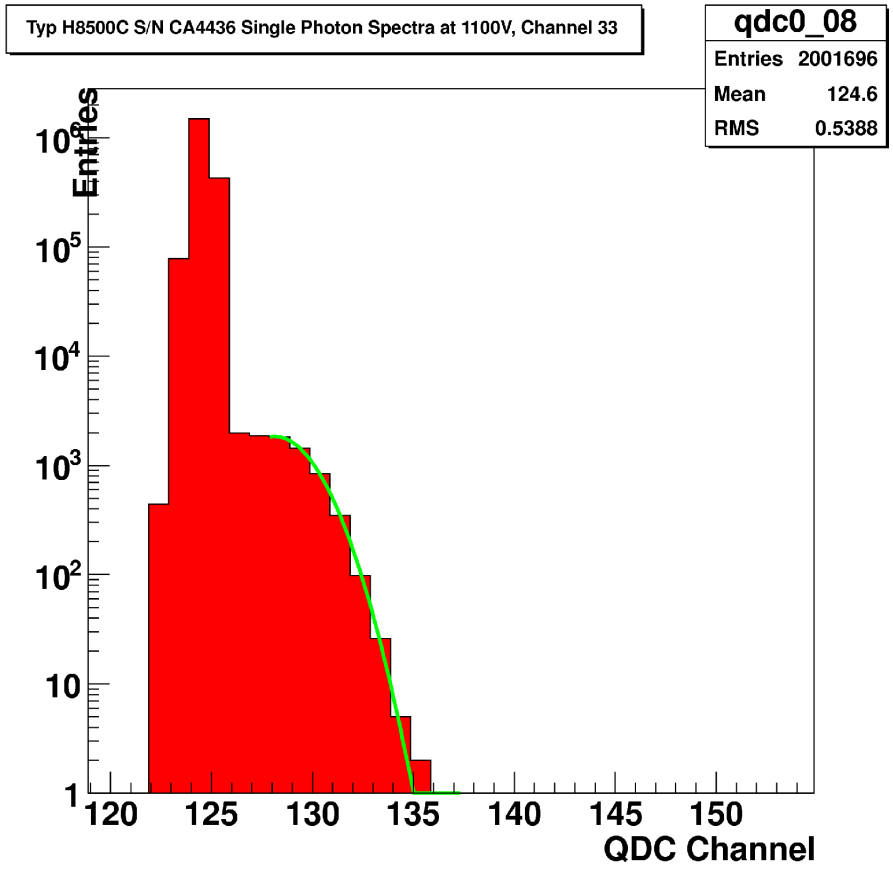


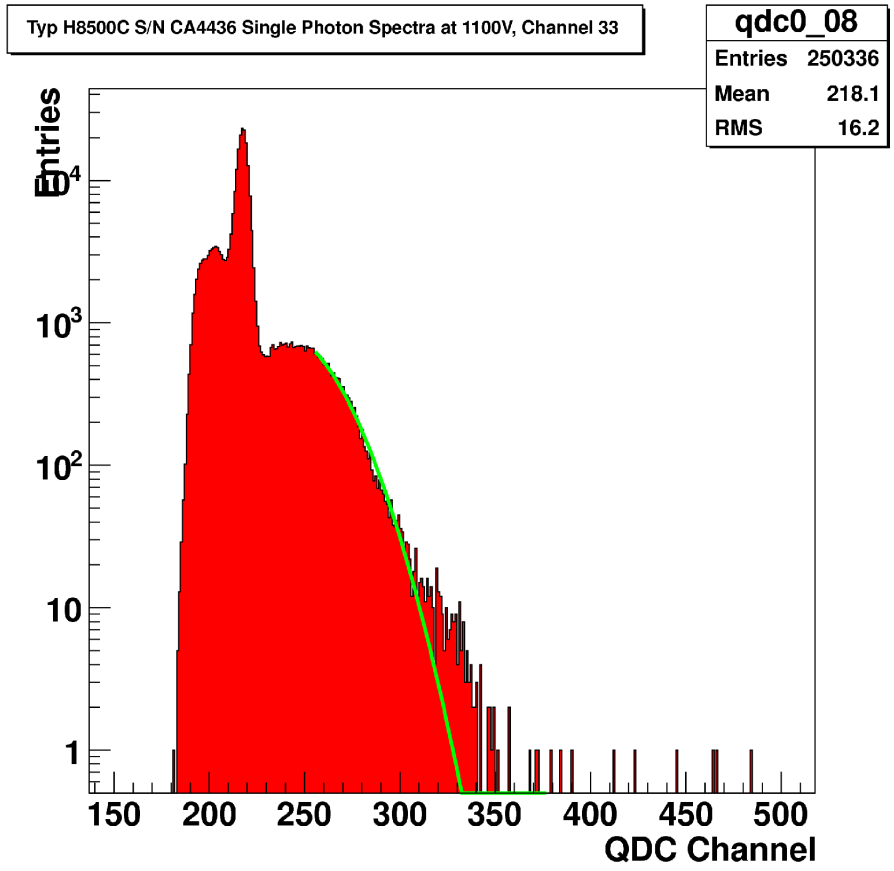


Pixel structure of CMOS

PHOTOMULTIPLIERS - H8500C

- Spectra with amplifier

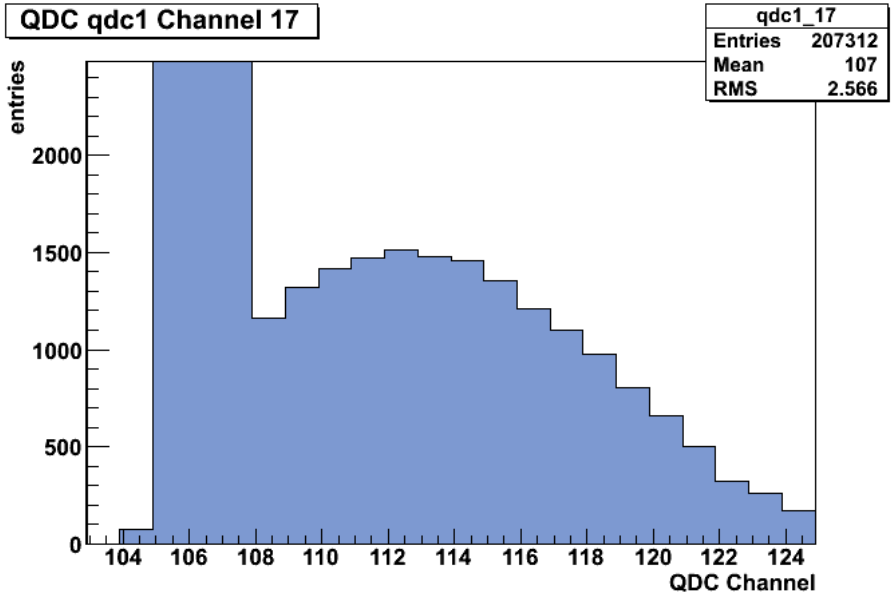


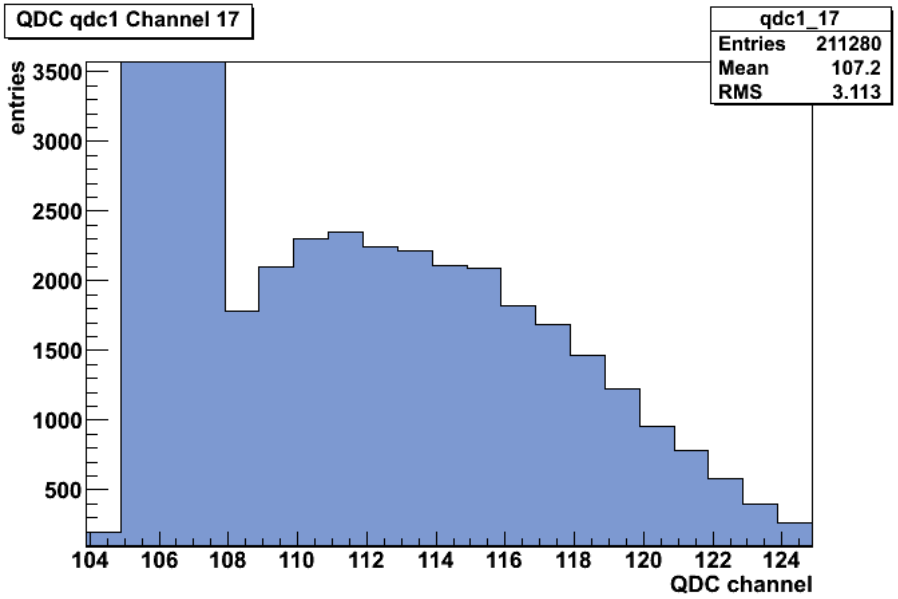


WASA-at-COSY

PHOTOMULTIPLIERS - H8500C

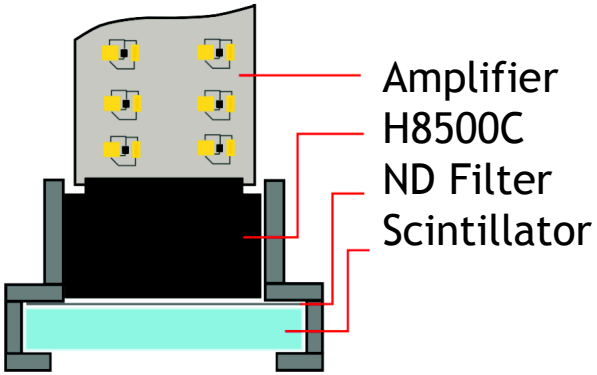
- Rate stability
  - laser pulser
  - single channel illuminated
  - QDC spectra @100kHz and 335kHz single photon

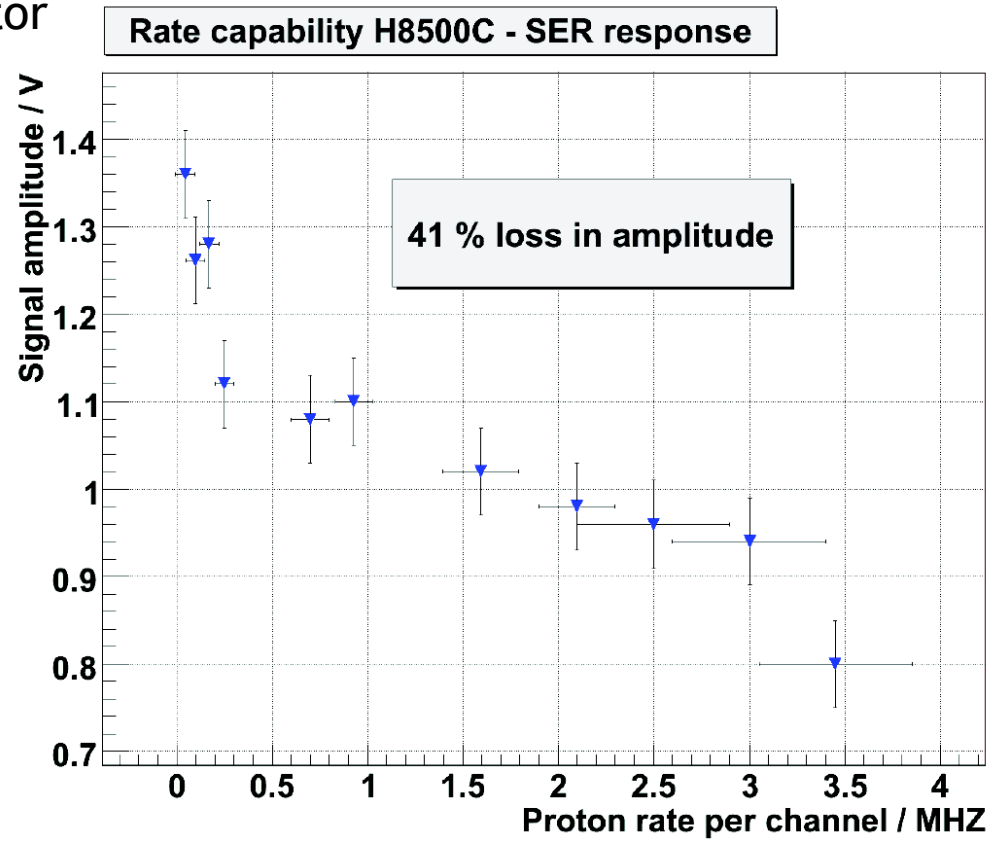




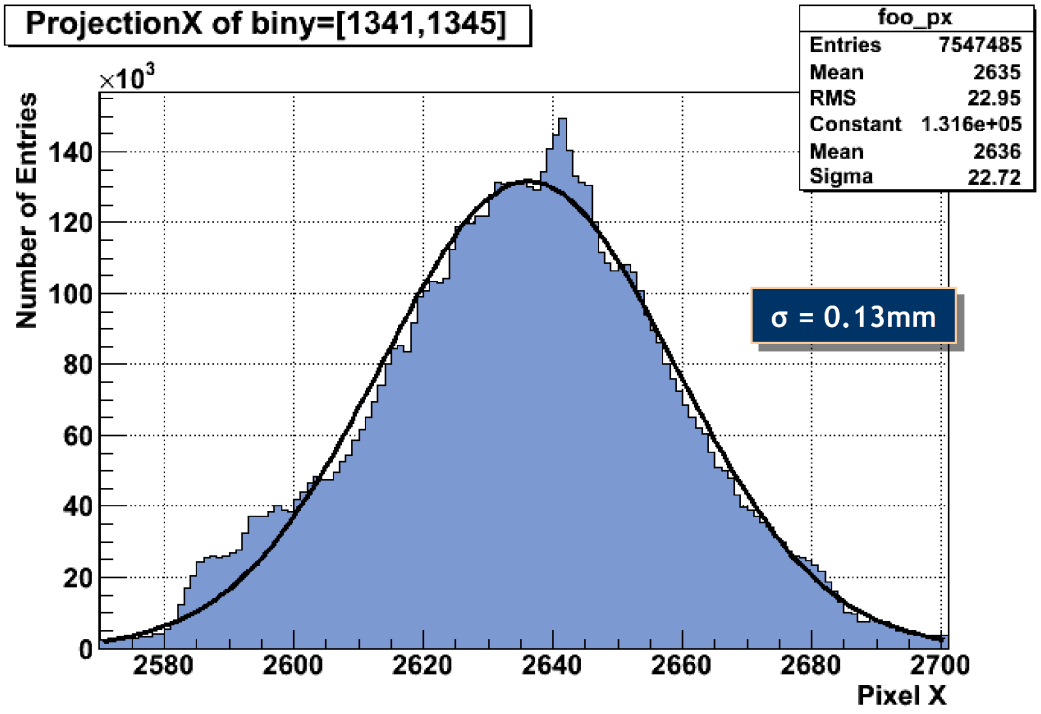
PHOTOMULTIPLIERS - H8500C

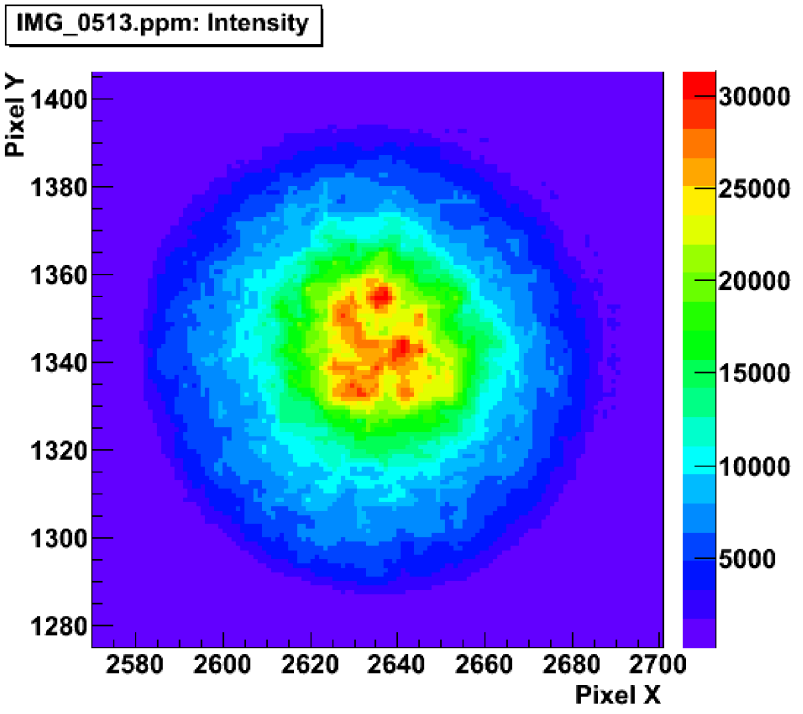
- Rate stability
  - 12 MeV protons in scintillator
  - all channels illuminated





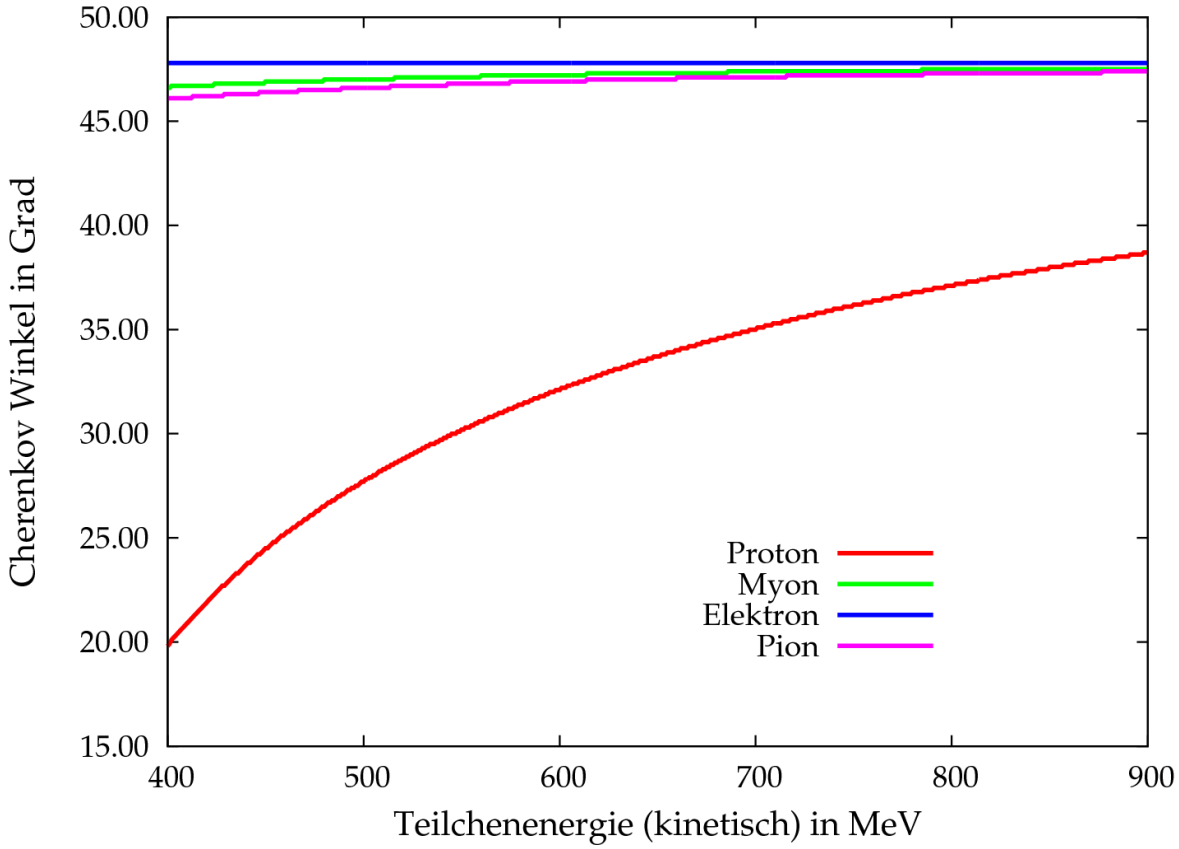
DAQ Laser



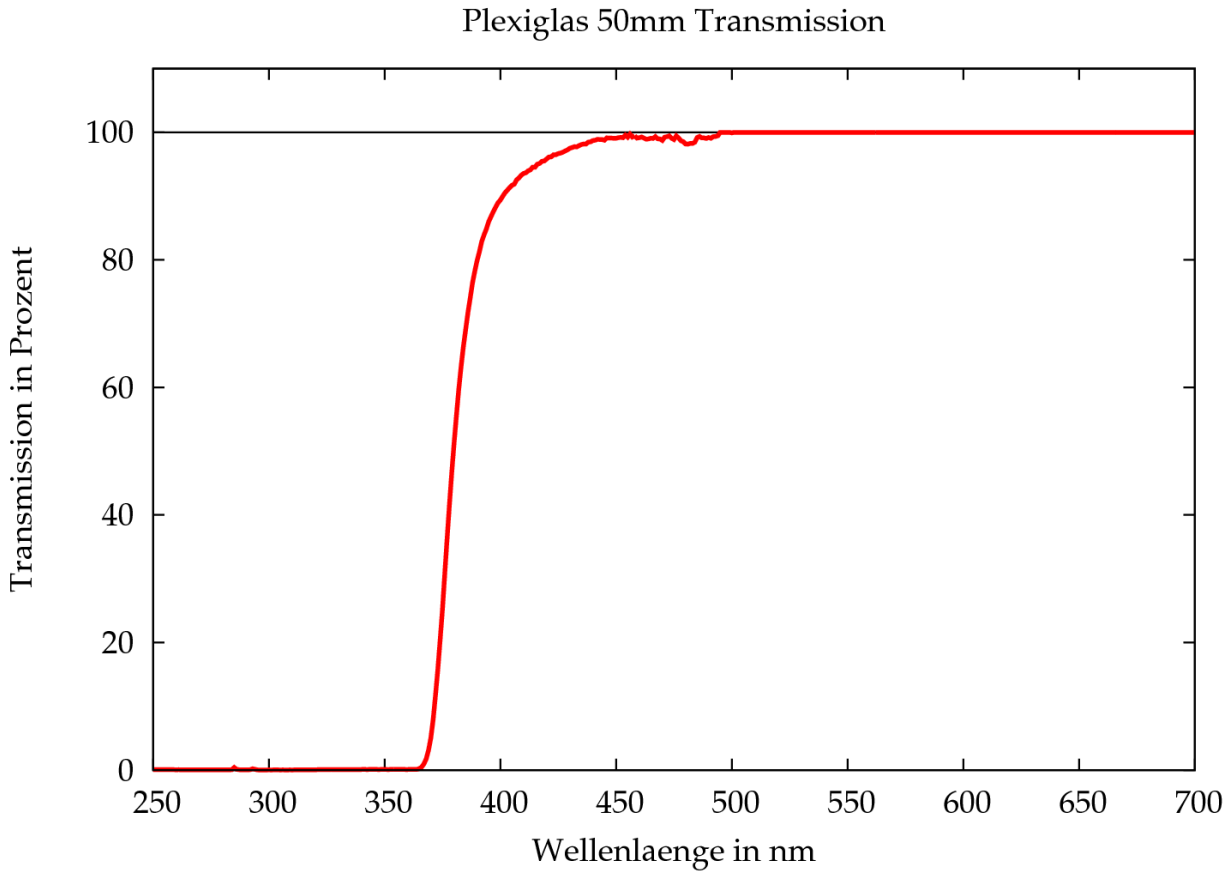


WASA-at-COSY

Cherenkov angles



Transmission of Plexiglas



Status of the TOF test stand

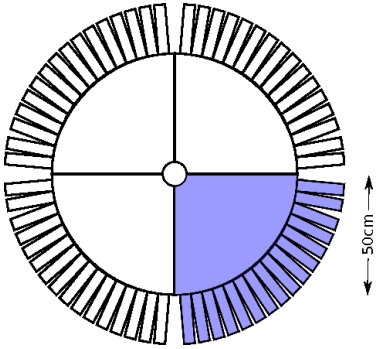
- Plan
  - use 14 64-channel an 12 16-channel PMTs for prototype readout
  - 1088 TDC and ADC channels needed
- Amplifier & discriminator channels at TOF
  - 400 (25x16) amps (max. 50x) and attached discriminators (0-148mV)
    - both twisted pair output (disc. ECL-pulses)
  - 256 (16x16) amps (max. 50x)
    - twisted pair output
- Discriminator channels at Erlangen
  - at least 320 (40x8) NIM-Modules with Lemo connectors
- DAQ
  - at TOF: FAST BUS ADCs and TDCs, at least 1500 channels both

PHOTOMULTIPLIERS – QE Studies

- All results from Christian Pauly (Uni Wuppertal)
- 8-stage (H10966-100)
  - SBA-cathode
  - q.e.@470nm : 25%
  - Gain @1100V: 1x10^6
- 12-stage (H8500C)
  - normal cathode
  - q.e.@470nm : 20% (in Erlangen ~17%)
- Tubes ordered by Erlangen, not yet delivered.

GIEßEN/TÜBINGEN

- Tübingen: Manufacturing of optics and radiator, assembly of prototype ongoing



- Gießen: